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THE CONCEPT OF NATURAL LAW IN GEOLOGY[1]

By Professor WALTER H. BUCHER

UNIVERSITY OF CINCINNATI

GEOLOGY operates largely without the concept of "natural law." The speaker became keenly aware of this circumstance when, a number of years ago, he began his efforts to derive from rapidly accumulating knowledge concerning the geology of different parts of the earth generalizations to form a reliable foundation for reasoning concerning the dynamics of the earth's crust.[2] When he spoke of them as "laws of crustal deformation," he had to meet the objections of others and his own doubts. He had to view the procedure of geologic investigations in the light of the fundamental methods of all science.

Some of the resulting reflections are presented here before men from many fields of science in the hope that they will lead to a clearer understanding of the nature of the geologist's work, and to that finer sympathy from which springs effective cooperation between men in different sciences upon which further progress depends in a large measure.

Geology is peculiarly dual in its aims: on the one hand, it is concerned with what happened *once* at a *certain place,* in *individual* mines, mountains, regions. Interest that centers on individuals is *history,* not science.[3] As a *science,* geology is concerned with the *typical* that finds expression in *generalizations,* whether they be called laws or something else. In his actual work, the geologist describes the individual and attempts to grasp its meaning in terms of the typical. If you catch him unawares, he will tell you that he tries to "explain" the "facts" of geology in terms of

[1] Presidential address read before the Ohio Academy of Science, at Toledo. A number of minor changes have been made in the final manuscript.

[2] Walter H. Bucher, "The Deformation of the Earth's Crust. An Inductive Approach to the Problems of Diastrophism." Princeton University Press, 1933.

[3] Heinrich Rickert, "Die Grenzen der naturwissenschaftlichen Begriffsbildung." Tübingen, 1929, esp. pp. 217–237.

the "laws of physics and chemistry." But the matter is actually much more complex.

For the purposes of the following discussion, we will do well to remind ourselves first of the essence of all scientific investigation and of the structure of science at large which results from it. Then we shall look at the scientific aspect of the geologist's work and the rôle which the concept of natural law plays in it.

Fairfield Osborn liked to tell the story of the little red-headed fellow he accosted in the elevator one day. "Well, my boy," said Professor Osborn, "what do you like best in the museum?" The little tot, in sepulchral voice, answered "fossils."[4] No doubt the circumstances justified the comic effect this answer produced. Yet the story sounds the funnier the less one knows about the mystery that attends the birth of a scientific career in a young mind. Every experienced worker knows of instances of children fascinated, without rhyme or reason, by a group of objects in a museum. They come back with longing eyes and at last overcome their shyness and ask questions. They want to know.

What is it they want to know? Generally, above all, what things are called—names. Few aspects of science amuse the layman more than what he considers the child-like delight scientists take in cryptic, if not bombastic, nomenclature. There are not a few men of science, in fields less encumbered by verbiage, who are inclined to share this sentiment.

Those who are closer to the realities of the descriptive sciences know better. The plain fact is that apart from troublesome taxonomic tangles every scientific name is a code word for a group of natural laws as significant and dignified as those of any science. When the boy-who-wants-to-know is told that the crystal he is holding in his hand is quartz, he is actually told that any substance of that crystal form, luster and fracture, always, by the inevitableness of experience which we call natural law, possesses a certain hardness, melting point, behavior towards acids, etc.[5]

If the shell he brought is *Polygyra,* he might be told: "Go back to the woods and collect a few shells just like this—they are common—but with the living animal still in it. You will find that animal possessing two pairs of tentacles, the larger ones each with an eye at the tip. You will find the mantle cavity lined with blood vessels, functioning as a lung. Dissolving the animal's head in potassium hydroxide, you will find a narrow ribbon beset with delicate teeth, many in a row, with specific shapes that can better be drawn than described, and so forth."

[4] Told by F. T. Davidson, president of the American Museum of Natural History. *Natural History,* Vol. 37, 1936.

[5] H. Poincaré, "The Value of Science," in "The Foundations of Science." The Science Press, 1929, p. 333.

To the boy such predictions would seem like magic had he not been told early to accept the dry fact that all things have certain properties. The "properties" of objects are the "laws" of the descriptive sciences.

Conversely, it might be said that the "laws" of the so-called exact sciences are but expressions of "properties." When, over three hundred years ago, Kepler recognized, as a result of observations that extended over more than a decade, that the orbit of Mars is elliptical, he merely discovered a "property" of the planet's orbit. This is true, even though his discovery required rare insight, being the result of keen abstractions from a very large number of observations concerning the position of the planet, and involving, furthermore, the assumption that the limited number of determinations was representative of an invariable form of the path.

In the same work (1609) in which he "described" the orbit of Mars, he published two of his bolder generalizations, the first of which stated that the orbits of all planets are ellipses. This, the first of the famous three laws of Kepler, has come down to us as a prototype of "laws." Yet it is purely descriptive.

It is true, it can be expressed in mathematical form. In that case we say, for instance, the paths of all planets are of the form $r = \frac{p}{1 - e \cos \vartheta}$.[6]

But that is no reason for calling it a "law" instead of a "property." Many of the "properties" found in the descriptive sciences can be expressed no less successfully in mathematical form. The shells of nautiloid cephalopods, for instance, grow in the form of a logarithmic spiral, in other words, assume an outline such that the advancing edge follows a path of the form $r = a\vartheta$.[7]

There is a better reason for calling some "properties" laws. It grows out of another aspect of scientific endeavor. The eager youngster in the museum asks not only "What?" but also "Why?" We are ready to tell him the properties of quartz and Polygyra. But then he asks, "Why is the quartz so hard?" and "Why does a radula with numerous, closely set, small teeth go with a shell such as Polygyra?" This is a more serious matter. He asked for "knowledge" before, now he calls for "understanding."

What, precisely, do we mean when we say we "un-

[6] Where r and ϑ are the variables in polar coordinates, p is the "parameter"—the length of the normal erected in the focus measured to its intersection with the curve—and e the "eccentricity" ($e = \frac{r}{d}$, where d is the distance from a given line, normal to the major axis). This is the general equation for all conic sections.

[7] Where, again, r and ϑ are the variables in polar coordinates and a is a constant. See the chapter on logarithmic spirals (Ch. XI) in D'Arcy W. Thompson's fascinating book, "On Growth and Form." Cambridge, 1917, pp. 493–586.

derstand," in matters of science? In place of giving an abstract answer, let us picture to ourselves what happened when men learned to understand a simple fact of nature, for example, the *rainbow*.

First of all, this common meteorological phenomenon had to be observed carefully so that it meant more than a curved streak of colors in the sky. Its properties had to be observed and defined carefully, each of which has truly the dignity of a law, such as, "rainbows are segments of circles; the center of the rainbow lies on a straight line drawn through the sun and the observer's eye; a single rainbow is always violet on the inside and red on the outside," and so forth. But even had he had all this knowledge, Aristotle had no means of understanding even the simplest elements of the geometry of the rainbow. He ascribed it to the reflection of the sun's rays by the rain. He must have felt as unconvinced as we do about many so-called "explanations" of present-day geology.

Two hundred years later Ptolemy made a good start toward a study of refraction in what has been described as "the most remarkable experimental research of antiquity."[8] But no one seems to have noted a possible connection with the rainbow. When the scientific spirit awoke again near the end of the Middle Ages, it was recognized that rainbows owe their origin in some way to refraction, perhaps combined with reflection. Real understanding had to await knowledge of the true law of reflection. When W. Snell discovered (in 1621) the quantitative law of refraction, Descartes was quick to apply it to the problem of the rainbow. His calculated angle agreed with that observed. Men now "understood" the geometric laws concerning the rainbow as special cases of the broader law of refraction. The colors, however, remained a mystery. There were futile attempts at explanations, of course. We would call them working hypotheses to-day. Men might even have entertained "multiple hypotheses" in their search for a solution. The fact remains that no matter how large a number of multiple hypotheses was made, no solution could be found until the basic law was discovered, and cast into suitable form, upon which the solution depended. When Newton found the laws of dispersion, understanding came in a flash. "Understanding," then, as we use the word in science, consists in recognizing a specific law as the special case of a more general law.

Newton's demonstration that all three of Kepler's laws, apparently so different in content, are merely the geometrical implications of an abstraction of by far more general character, is perhaps the most illustrious example of an intrinsically great feat of understanding.[9]

[8] G. Sarton, "History of Science," Vol. 1, 1927, p. 274. Quoted from W. C. D. Dampier-Whetham, "A History of Science," 1931, p. 54.

Quite instinctively, certainly without any particular method, we speak of "laws" when we recognize generalizations that are fraught with possibilities of understanding—in contrast to those generalizations which establish relationships to be understood—the properties. Thus we speak of Osborn's law of adaptive radiation in biology, of Ferrel's law in meteorology, of Rosenbusch's law in petrography. The more general a law, the greater its resolving power. In order to be general, it must be abstract. The more abstract it is, the more amenable it is to mathematical treatment —the more exact is the form in which it can be stated.

The sciences that face the objects of experience in their full complexity—such as the plants, animals, rocks, topography, weather—find the mathematical language inadequate to their task. The curves defining the shape of a trilobite or of a granite intrusive, like the flow lines of a weir in a river or of the air on a weather map, defy mathematical analysis. Accurate description of reality seen in nature and in experiment form the accumulated store of scientific knowledge in these sciences. From it there arise, through judicious generalizations, "specific laws" that give us the first sense of order in the concrete aspect of complex reality. Back of them, revealed by greater and greater abstraction from reality, we distinguish the more and more general laws of chemistry, physics, mechanics, electrodynamics, mathematics. This is the familiar picture of the hierarchy of the sciences. It is repeated in the structure of each branch of science.

In geology, we see geophysicists, students of geotectonics, regional geologists, stratigraphers, petrographers, mineralogists gather observations that are to lead ultimately to an understanding of the complicated spectacle of the earth. Like horizontal strata of decreasing complexity, lie the levels at which these men are working, each forming at least part of the foundation for the work of those above it.

At each level laws must be formulated without which understanding is impossible at the higher levels of complexity. This is the picture the geologist must keep before him if he is to do his best work and derive the deepest satisfaction from it.

Let us now see how this works out in practice. Take the case of the igneous rocks. Observations led early to the definition of numerous types and to attempts at classification. Mineral composition and texture were studied comparatively. Here, as always, comparative studies led to generalizations which were more than mere properties of types, generalizations that had the

[9] The proof with the mathematical tools that Newton had at his disposal was a very great achievement indeed. In modern vector notation the proof is quite simple and occupies not more than two pages for all three laws. See Louis Brand, "Vectorial Mechanics," New York, 1930, pp. 401–403.

character of empirical laws. "Nephelite-bearing rocks are free from quartz," is one. Rosenbusch's law concerning the typical sequence of (final) crystallization, from basic to acid minerals, is another.

Not until such laws were formulated could any serious desire for explanations, for "understanding," arise. Before, it would probably have seemed rather silly to ask, "Why is a basalt constituted the way it is?" One might as well ask, "Why do radulas of the Polygyra type go with the shells that characterize that genus?" That is the way it is—that is all.

It would certainly have been futile to go to the classical chemistry of the last century for an answer. No number of multiple hypotheses could have led to the trail of understanding; because understanding could not even be conceived until physical chemistry had reached the state of the phase rule.

But even after the basic concepts had been created, much work had to be done before an understanding of the characteristics of mineral associations in igneous rocks became possible. The level between the abstract theory and the complex reality of the rocks had to be filled by experiment on the properties of silicate melts. Investigations in that field are expensive. Industry was slow in entering that no-man's land. When the geophysical laboratory of the Carnegie Institution of Washington was established, it undertook to fill the gap.[10] The Kaiser Wilhelm Institute für Silibatforschung in Berlin-Dahlem was modeled after it. For over three decades the work has gone on. One by one the empirical laws of petrography are becoming intelligible, if not fully understood, in the light of the properties of silicate melts. Thus formulation of empirical laws, systematic exploration of artificially simplified systems: those are the steps from which springs the understanding of reality which is the ultimate aim of science.

Let us turn to another illustration. In a sense, mineralogic-petrographic studies on igneous rocks are not typical of geologic work. The units with which they deal can be taken into the laboratory, weighed, studied under the microscope, analyzed chemically.

Geologic investigations in the strict sense of the term, on the other hand, deal with sizable parts of the earth's crust. While these are, of course, small compared with the objects studied by the astronomer, they have the disadvantage of being right up against us. They are vast compared to man's size. The amount of physical labor and time consumed in merely traversing the objects of study looms large. The methods of the surveyor and cartographer and graphic representations of diverse kinds must be used to record the knowledge gained. In typical cases the work of several men and of several field seasons is required to furnish a reasonably accurate description of one object of study, one individual, if you please.

Take the case of the oil-bearing strata of the Green River shale—sediments of a long extinct lake in western Colorado, Wyoming and Utah. In order merely to describe this stratigraphic individual adequately, it is necessary to traverse along as many lines as possible the 25,000 square miles covered by these sediments; to study the variations in the sediments, especially the near-shore phases; to measure the rhythmic lamination of the sediments, which is such a conspicuous feature of the formation, throughout the 2,000 feet of thickness and to compare the results for as many sections as possible; to look for and study carefully zones with significant minerals, such as a rather unique analcite bed and more numerous layers of other peculiar minerals; to study the nature of the organic material, chemically and above all with the microscope and microtome; to make collections, as exhaustive as possible, of the fossil leaves, insects, fishes, for which the beds are famous, and to establish the taxonomic identity of the microscopic and megascopic forms found. Vast labors in the field, in the laboratory, the herbarium and museum by a score or more of men were needed to complete, in the course of years, a reasonably accurate description of this formation.

The result of all this labor is the description of a *single individual*, one body of deposits. No laws can be derived from this individual. But laws are needed to understand its properties.

Take the most conspicuous property of these beds, the fine lamination that runs with mathematical accuracy through every microscopic section, in endless alternations of pairs of layers, measured in tenths of millimeters, one chiefly organic matter, the other largely inorganic. What does it mean?

Many possible explanations come to mind. The geologist, more than other men of science, must work with multiple hypotheses. For understanding, the geologist turns to limnology. One "law" of limnology suggests an explanation: the plankton of lakes reaches annually a relatively short peak, dropping to a minimum for the rest of the year. The microscope shows that the organic matter of the laminae consists of plankton. Here is a possible answer. Another "law" of limnology[11] points to the same answer: the deposits

[10] It is instructive to read the diverse suggestions which were received by the advisory committee on geophysics from outstanding geologists and geophysicists, at the founding of the Carnegie Institution (Year Book No. 1, 1902, pp. 44–70) and contrast with them the purposeful limitation of the work which was ultimately adopted and which has led to such uniquely valuable results.

[11] B. W. Perfiliew, "Das Gesetz der Periodizität der Schlammbildung und die Tiefgewässer-Bohrung." Verh. Intern. Verein. f. Limnologie, 1931, Vol. 5, pp. 298–306.

at the bottoms of modern lakes show similar alternations of organic (planktonic) and inorganic laminae.

The Green River beds represent part of the Eocene period. Radioactive minerals have furnished data which give a rough estimate of the length of the Eocene period. This can be compared with the length of time represented by the fraction of it comprised in the Green River shales, computed on the assumption that each pair of laminae records one year. The figure found, 6,000,000 years, compares favorably. One more test suggests itself. The thickness of the pairs of laminae is variable. If they represent deposits of one year each, their varying thickness must somehow be connected with fluctuations of climate. A "law" of climatology proves useful: climatic variations proceed in complex curves in which definite cycles are recognizable. When plotted, the laminae of the Green River shale reveal the same cycles.

Thus each new investigation points in the same direction: we are getting nearer and nearer to a satisfactory understanding.[12]

This case is typical of geological work. The empirical laws formulated in the course of studies on living environments and processes—although not labeled as such—form the means of understanding the properties of an individual of stratigraphy—the Green River lake beds.

But there are other famous fossil lake beds—like those of Florissant in Colorado or of Oeningen in Switzerland and many others, little studied. As one by one they are described and analyzed, common properties will be recognized and formulated. There are already in existence interesting discussions of the "Criteria" for lacustrine sediments.

The field of structural geology represents a higher level of complexity in geologic studies. In certain belts the strata of the earth's crust lie deformed: broken by fractures, or crushed along shear zones, bent into folds and thrust one on top of the other along thrust planes. Here the difficulties in the way of study are multiplied. Even if the earth's crust were transparent and the actual features of the deformation could actually be seen to the depth of a mile or two, the mere task of recording, in intelligible manner, the three-dimensional pattern of a folded mountain chain would present great difficulties. With only the surface accessible to the eye and most of it concealed by vegetation and mantle rock, the unraveling of the structure of such regions as the Alps or the Scottish Highlands represents a herculean task, for the body as well as the mind.

While the anatomist can produce hundreds of sections with his microtome in a fraction of an afternoon, it takes years of topographic surveying and decades of geologic mapping, each man refining and correcting the observations of his predecessors, before a series of reasonably accurate cross-sections can be produced through such a region as the Swiss Alps or the folded Appalachians. Here again, then, the descriptions of individuals is still, by force of circumstances, the dominant occupation of the geologist.

Nevertheless, it is just in this field that the search for typical patterns, for laws of deformation began early. Types of folds and patterns of fractures were early recognized and given names. The practical importance of many structural features in mining and prospecting led to a high development of the formal aspects of rock deformation. As early as 1878, Albert Heim's "Untersuchungen über den Mechanismus der Gebirgsbildung" brought exemplary precise formulations of valid generalizations.

But understanding of the structural facts in terms of more basic laws has barely begun. For classical physics, proceeding along strictly inductive lines, had limited itself at first almost entirely to the simplest aspects of the deformation of bodies, which are below the elastic limit, where relatively simple equations can be tested by crucial experiment. Valiant attempts were made by geophysicists to attack the problems of rock deformation with the inadequate tools of the classical theory of elasticity. Papers were written that were learned but not convincing. Understanding could not be expected until physicists ventured forth from the abstract field of simplest cases into the realities of the world of bodies at large. This time industry has filled the gap with its practical demands, and a new empirical science, the physics of materials, has come into existence. Such basic properties as plasticity, strength, rigidity, brittleness are being studied exhaustively. Empirical laws are being cast into mathematical form. Fracture patterns and other forms of deformation are being studied and analyzed. In that way laws of behavior of materials are being formulated out of which ultimately will come a true insight into the nature of geological structures.

One phase of modern studies of granite massifs may serve as a concrete illustration. At the time when the merciless inflation of the after-war period crippled the activities of many German geologists by making distant traveling impossible, Dr. Hans Cloos at Breslau took a devoted body of students into the numerous granite quarries of the near-by mountains of Silesia and carried on systematic studies of the innumerable fractures that cut every granite body in nature.[13]

(Known to the writer at present only through a review in *Bot. Zentralbl.*, Vol. 164, p. 98, 1931, to which Dr. Th. Just called attention.)

[12] I have quoted from a series of classical investigations by W. H. Bradley, of the U. S. Geological Survey. See especially U. S. G. S. Prof. Paper 158, 1929, pp. 87–110; *ibid.*, Prof. Paper 168, 1931, 58 pp. and 28 plates.

[13] He carried out near his home investigations inspired in pre-war days by his careful studies of beautifully exposed granite regions in the deserts of Southwest Africa.

Thousands of readings giving the attitude in space of all important fracture surfaces observed were plotted graphically. Soon definite systems of fractures were recognized that run uniformly through a granite mass: fractures aligned at right angles to the strike; longitudinal fractures; conjugate shearing planes, and pinnate fractures along the contacts. This assemblage of fractures has since been found to be practically universally present in intrusive bodies of granite.[14] Their presence constitutes empirical laws of great value.

When these empirical laws had been established, Dr. Cloos undertook to supply the knowledge that was needed for understanding. In a series of ingenious laboratory experiments, he has attempted to reproduce the essential aspects of orogenic deformation. Reasoning in terms of factors of similitude, he used a mixture of water and clay for his experiments, a substance yielding to gravity and yet of such coherence as to fracture after the fashion of such solids as granite.[15] When he showed his extraordinary results at the next International Congress, more than one geologist shrugged his shoulders: "What can one learn from wet mud about granite?"

The highest degree of complexity is reached when the earth as a whole becomes the object of study—in what is now widely called geotectonics. Here it is not the details of structure of individual mountain ranges, but the pattern of folded mountains on the face of the earth as a whole that demands attention; not the relations of one plateau to another, but that of the continental platforms to each other and to the oceanic floors; not the events of volcanic outbursts in one region, but the connection that exists between belts of volcanism and belts of deformation; and so forth.

To the complexities of three-dimensional structure, the time element is added as the fourth dimension. The geologist's intricate and still very crude methods of relative timing must be used to determine whether epochs of folding are short, spasmodic events, or long-drawn-out processes; whether mountain folding takes place simultaneously in many parts of the earth followed by periods of quiet or whether some folding has been going on somewhere on earth throughout geologic time; whether epochs of mountain folding coincide with times when continents became submerged by a rising sea level, or with times of emergence—and so forth.

In the four volumes of "The Face of the Earth," a work of rare compass, depth and beauty,[16] the product of thirty years,[17] Eduard Suess has laid the foundation for all such inductive studies concerning the deformation of the earth's crust. In this work the masterful picture of the then available knowledge of the structure of the whole face of the earth, covering over 2,700 pages, culminates in a few chapters of "Analyses" and "Hypotheses" of only 138 pages[18] which grip by their moderation, the tentative and cautious tone of their interpretations. Fertilized by the fervent enthusiasm and the almost inexhaustible riches of this work, structural analysis has since been carried on systematically into most parts of the world. The detailed literature on regional tectonics has grown beyond the grasp even of a genius. But the growing number of authentic summary accounts and of tectonic analyses of limited areas, on the other hand, is making accessible more and more the generalized results from many parts of the earth. From them gradually broader generalizations are being derived that hold good everywhere to-day and will stand the test of future observations, generalizations that are true "laws." A few such laws were established long ago, as, for instance, Elie de Beaumont's law of the episodic character of orogeneses (1829); Godwin-Austen's law of the tendencies of posthumous folds to trend parallel with the lines of earlier folding (1856); Hall's law of the coincidence of belts of folding with belts of abnormally thick sediments (1859).

Ten years after Suess' death, Stille published his "Grundfragen der vergleichenden Tektonik."[19] The title of this remarkable work makes effective use of the expression "Comparative tectonics" and the text culminates in the formulation of a "law," Stille's "orogenes Zeitgesetz."[20] It is a broad generalization based on two properties of orogenic movements concerning their incidence in time. It is a general law of broad resolving power. The writer believes it to be valid. But geologists are by no means agreed that the two properties on which the law is based are really general and essential. Such a generalization can hardly be called more than an "opinion," until it can be shown to rest on a valid basis. On the whole we are not ready to formulate such broad laws. The first

[14] For a bibliography of papers by Cloos and his collaborators, see Robert Balk, *Bull. Geol. Soc. America*, 36: 695–696, 1925. (A larger paper by the same author, entitled "Structural Behavior of Igneous Rocks," will soon appear as one of the Memoirs of the Geological Society of America.)

[15] The following papers deal with tektonic experiments of this type in general: H. Cloos, *Centralbl. f. Min.*, Abt. B, 1928, pp. 609–621; *Natur und Museum*, 1929, pp. 225–243; *ibid.*, 1930, pp. 258–269; *Naturwissenschaften*, 18: 741–747, 1930; *Geol. Rundschau*, pp. 353–367, 1930; *Naturwissenschaften*, 19: 242, 1931.

[16] In his epilogue to the French edition, Termier has called this work "bien un poème, dans le sens complet de ce mot splendid qui veut dire création." "La Face de la Terre," Vol. 3, pt. 4, p. 1713, 1918.

[17] Eduard Suess, "Das Antlitz der Erde," Vol. I, 1883; Vol. II, 1888; Vol. III, pt. 1, 1901; Vol. III, pt. 2, 1909.

[18] In the English edition of Sollas and Sollas.

[19] Berlin, 1924 (Gebr. Borntraeger).

[20] *Loc. cit.*, pp. 44–45.

task is to crystallize knowledge concerning the observable properties of the structure of the earth's crust. Stille's book is primarily devoted to this task as far as the time element in orogenesis (and epeirogenesis) is concerned. The speaker has attempted to extend this work to other properties. On the strength of the convictions set forth in this address he spoke of them as "laws," *i.e.*, "specific laws" of crustal deformation, from which ultimately such "general laws" as Stille's will be derived. He might have listed his "specific laws" as "properties." He preferred the more challenging "law." The word he could not use, suggested to him more than once, was "theses." "Too much of the geotectonic literature of the past was concerned with the theses of men rather than with laws of nature."[21]

This, then, is the essence of all geologic work:

(1) Not to be satisfied with the accumulation of facts alone, but to draw from them, at every opportunity, all possible generalizations. In other words, to search for the general properties, the "specific laws" in the reality with which we deal, and ultimately for such "general laws" as can be safely formulated.

(2) To seek understanding of the empirical laws thus found by studying the findings of workers in the nearest level of complexity. For the geologist, that means stepping from the records of the past to the experiences of the present; from the properties of vast bodies to those of small units of the laboratory; from the complex systems of nature, to simpler systems capable of analysis. It means oceanography, limnology, hydrology, the physics of materials, the physical chemistry of silicate melts, and so forth, not simply elementary text-books of chemistry or physics.

Neither of these two points is followed as widely as one should expect. As to the first, a multitude of facts is still published with little or no evidence of thought concerning their broader bearings. As to the second, uncontrolled speculation still too often takes the place of that systematic searching for an adequate foundation for understanding which is needed. When we try to understand the Permian glaciation, we still invoke movements of the continents or of the poles (or both), instead of instigating that prolonged systematic research by competent meteorologists which alone can make sure that wide areal glaciation down to sea-level is impossible in equatorial latitudes; we use similar speculations when we speak of the existence during the geologic past of higher vegetation near the poles,[22] without having brought about investigations needed to decide if trees can grow where the night and day last half a year each; we demand vertical uplift of the continental shelves of nearly two miles to "explain" the submarine valleys before having placed the problem into the hands of experienced hydrologists familiar with the complex currents set up by the tides, and so forth.

Speculation that does not lead directly to further search for facts and laws is idle. The joy of understanding arises from reasoning, not from guessing; from the purposeful grouping of general facts, not from the mere play of the imagination.

Two things remain to be said. One refers to the human side of this task. The other points to the future outlook.

For the human side let us turn back once more to the boy-who-wanted-to-know in the museum. Let us assume that his enthusiasm held out through his high-school years—we are optimists, you see. He has pushed through as fast as possible, impatient of any delay, to that field of science which at the time satisfied his fancy. He has become a geologist. The more he learns about the strata and structures, the less he is satisfied with the mere description of "facts." He turns to basic works on limnology, hydrology, physics of materials. And now he finds much that he can not read. Not only a strange terminology, but the unfamiliar concepts and lines of reasoning of the basic sciences: physical chemistry, vector mathematics, statistics, etc. He wishes he had become a mathematician first, then a physicist and then a chemist. He looks with envy upon those whc work in the abstract fields of artificial simplicity, where knowledge is exact and reasoning rigorous. His own problems seem muddled, his own mind inadequate.

But when he seeks cooperation from the fortunate ones who are mathematicians and physicists, he makes a discovery. Just as he, in the typical case, at his stage of life can not spend the energy and time necessary to acquire a working knowledge of the mental tools of the basic sciences, so the workers in the abstract sciences find the task too great to acquire the perspective over the intricacies of unabstracted reality without which creative work is impossible. Moreover, he who is accustomed to the "linear order of thought which is necessarily cultivated in . . . mathematics" finds it distasteful, if not difficult, to acquire "the habit of parallel . . ." or "complex thought," as T. C. Chamberlin[23] once called it, in which a multitude of interrelated properties must be visualized and weighed as parts of an integral whole.

The recognition of this difference is wholesome.

[21] Walter H. Bucher, "The Deformation of the Earth's Crust," p. vii (Preface). Princeton, 1933.

[22] Since this was written, coniferous wood of araucarian type has been reported, found together with leaf impressions of cycadophytes in an Upper Triassic or Jurassic florule associated with coal, which was collected in south latitude 86° 58′, *i.e.*, within 3 degrees of the South Pole. Wm. C. Darrah, SCIENCE, 83: 390–391, 1936.

[23] T. C. Chamberlin, *Jour. Geol.*, 39: 164, 1931. Reprinted from the original in *Jour. Geol.*, 5: 837–848, 1897.

Every geologist needs such an experience to find the right pride in his work. The worker in the complex levels of science is the explorer, the man from the basic sciences the guide. One derives his significance from the other, and both derive the sense of dignity in their calling from the joint goal which is an ordered insight into complex reality.

As to the outlook for the future: I have spoken so far of two steps that enter into the mental process of the geologist. But there are really three:

First comes *analysis, "re-solving"* the complexity of geological reality into its constituent, essential elements of orderly recurrence, formulated as generalizations which we call "properties" or "specific laws."

Second, *interpretation, "translating"* these "properties" or "specific laws" into the terms of the more "general laws" of the basic sciences. This constitutes "understanding."

The third is *synthesis, "putting together"* again, collecting in our consciousness the numerous threads of understanding into one adequate perspective of nature as we see it in its entirety. "Analysis" is in full swing. "Interpretation," and with it "understanding," is growing, as laws are being formulated in the fields of investigation that lie between geology and the basic sciences.

But in the larger aspects of geology the final synthesis which is to give us a satisfying, logically consistent and coherent picture of the earth's crust and the forces that have formed and are forming it, is a hope for the future. It will be brought about by the growth of a tendency which is taking form now. Analysis produces specialists; the growing need for synthesis will produce encyclopedists. H. G. Wells put it this way: "The world, if all goes well with it, will consist very largely of specialists, who know every detail about and every relationship of something, and of people . . . who will know everything in outline and in correlation. Specialism and encyclopedism are necessary correlatives."

Analysis and interpretation require the field and the laboratory. Synthesis is done in the philosopher's study. Most geologists, and for that matter most scientists at large, mistrust the man who studies not nature, but natural laws. His work looks like the boring and hoarding of the bookworm. Most scientists are still unaware of the difference between unimaginative compiling, the cataloguing of facts, and the creative power that is required for all true synthesis. Yet it is such synthesis alone which can make us fully aware of nature. For, to see the work of many in one perspective, to realize the common bond of natural law that permeates all our experience of nature, means to realize the "internal harmony of the world" which, as Poincaré pointed out repeatedly,[24] is "the only true objective reality," the ultimate goal of all science.

THE STRUCTURE OF NATURAL AND SYNTHETIC ANTIGENS[1]

By Dr. MICHAEL HEIDELBERGER
PRESBYTERIAN HOSPITAL, NEW YORK

WERE I to confine my remarks, in opening this discussion, to a literal interpretation of the subject or to definitely established facts, our committee's generous time allowance would be much too long. I must therefore risk your disapprobation, to fill the time allotted, by taking a broad view of the topic and by entering occasionally upon the realm of the speculative. As I have taken the bit in my teeth, let me also give credit here to all my colleagues in this field, and since you will have no difficulty in recognizing the contributions discussed, I may be permitted to save time by mentioning few names.

With regard to the structure of the natural antigens of the type of the animal proteins there is little that can be said. Denaturation effects a change in specificity, as does also reduction of disulfide linkages, but the latter effect may be due to a splitting of the molecule at the –S–S– linkage as well as to the conversion of these groups into –SH. Of greatest promise, however, has been the work of Bergmann on gelatin and Waldschmidt-Leitz on clupein, substances which are not antigens at all. Extension of these fundamental researches on the number and arrangement of the amino acids to more complete proteins will afford a direct approach to an understanding of the chemical basis of the specificity of proteins, the class of substances to which most antigens belong. Work along these lines should eventually clear up the riddle of species specificity and tell us why, and how, for example, horse serum albumin differs from human serum albumin. While it is probably the occurrence of definite groupings of amino acids which confers the property of serological specificity on these natural

[1] Opener's address, Joint Discussion on the Structure of Natural and Synthetic Antigens, Second International Congress for Microbiology, London, July 27, 1936.

[24] H. Poincaré in "The Foundations of Science." The Science Press, pp. 207, 209, 1929.

antigens, the completeness of their antigenic function would seem to depend upon the ordered recurrence of these groupings to build up a multivalent whole. It is likely that these groupings contain aromatic nuclei, and it is also probable that the ε-amino groups of the lysine component play a part.

In addition to the animal antigens there is another antigenic group of deep significance—the antigens elaborated by the bacterial cell. Comparatively little is yet known of the bacterial cellular proteins except that they represent exceedingly complex mixtures and that fractions isolated under conditions likely to reduce enzymatic and chemical changes to a minimum usually contain more or less nucleic acid, all or part of which may be combined as an ester. Most fractions also contain carbohydrate in excess of that ascribable to nucleic acid, to which I shall refer later. To attempt to classify these proteins as "albumins" or "globulins," or to speak of their precipitability by acetic acid as an indication of "denaturation," as has been done, is, I believe, premature and out of harmony with the accepted usages of these three terms. Little is known, as well, of the bacterial toxins, except that they appear to be proteins, or only slightly degraded proteins.

Until twelve or thirteen years ago it was assumed that only proteins could be carriers of the antigenic function, but the discovery that polysaccharides are the determinants of type specificity among the encapsulated bacteria greatly widened the scope of immunochemistry and cleared up several puzzling problems. Indeed, owing to the nature of the carbohydrates, the chemical basis of specificity in this group is far better understood to-day than among the proteins, but even here our knowledge is fragmentary. With the discovery of a labile acetyl group in the specific polysaccharide of Type I pneumococcus, many of the conflicting reports in the literature were reconciled and explained, and there seemed little more to be done than to work out the chemical structure of this unusual nitrogen-containing polygalacturonide. We have just been made aware, however, that the Types I, II and III pneumococcus specific polysaccharides are not even stable to heat, as has been supposed for so long. The use of absolute, quantitative methods of immunological analysis, of which I shall speak on another occasion and which were not available at the time of the earlier work, has brought out this thermolability very clearly, and the irreversible drop in viscosity of specific polysaccharide solutions when heated is an even more sensitive indicator of a change which is probably a depolymerization.

I may mention, also, that preliminary ultracentrifugal studies on the specific polysaccharide of Type II pneumococcus, in which electrical effects would be expected to be much less than with the Type I or Type III substance, indicate that the particle weight of even the unheated carbohydrate is relatively small. Moreover, when we consider that some thirty serological types of pneumococcus are known, each of which must be characterized by a chemically distinct specific polysaccharide, and that only the carbohydrates of Types I, II, III, IV and VIII have been studied and at least partially identified, we must admit that even the much worked over field of pneumococcus immunochemistry is woefully incomplete.

The question of the antigenicity of specific polysaccharides is an interesting and complicated one. It would appear that, given a suitable, undegraded preparation, and a suitable animal such as the mouse, or a suitable route of injection into other animals, as for example, the human skin, specific polysaccharides may function as antigens and directly stimulate the production of antibodies. Landsteiner has just shown, however, that even simple aromatic substances may share this property, which is perhaps due to their ability to combine with certain tissue proteins to form new antigens. Another recent development is the finding that protein fractions of meningococcus, streptococcus and tubercle bacillus, when injected into rabbits, quite regularly give rise not only to antibodies reacting with the bacterial protein, but also to antibodies which precipitate the somatic specific polysaccharides of these microorganisms. Since the mere mixture of a specific polysaccharide with protein does not suffice to render the carbohydrate antigenic for rabbits, it must be concluded that these protein fractions contain specific polysaccharide in chemical combination, and this has been further indicated in the case of streptococcus by actual chemical analyses. While the carbohydrate in synthetic carbohydrate-protein antigens has been shown to be immunologically active, these are the first instances in which such activity has been definitely indicated in a natural protein antigen. The question is also of importance in connection with the hunt for the elusive pneumococcus type specific antigen which has always been assumed to be a labile carbohydrate-protein complex.

There is one other phase in the development of polysaccharide chemistry which never fails to afford me a quiet chuckle. You will recall that the specific polysaccharide of Type III pneumococcus was found to be a polyaldobionic acid, that is, composed of units of glucuronic acid linked to glucose. Since then, it has been discovered that aldobionic acids form an important part of the hemicelluloses and plant gums, so that actually untold numbers of tons of these sugar derivatives exist. Thus, even though the woods were full of them, the first aldobionic acid was found in the capsular substance of a pathogenic microorganism.

Two other most important classes of natural anti-

gens are the filterable viruses and bacteriophage. The chemical study of these antigens is in its infancy, but will, I feel sure, occupy a prominent place on the agenda of the next international congress. At present the weight of evidence would appear to favor the view that 'phage and some of the plant viruses, at least, are not living agents but proteins capable of increase in some such autocatalytic fashion as Northrop and his collaborators have found in the case of certain enzymes. Tobacco mosaic virus, for example, could not be separated from a most unusual crystalline protein of particle size greater than that found for any other protein.

Whether or not to include lipins among the natural antigens is still uncertain. Too often the serological work on this subject has been without adequate chemical control and, in more than one instance in which isolation of the serologically active so-called lipin has been attempted, much of the lipin character has been lost during the process of purification. Although on chemical grounds lipins should possibly be capable of functioning antigenically as well as carbohydrates, for example, the few apparently authentic instances of such action may well be due to carbohydrate-lipin complexes such as have been found in the Forssman hapten and among the specific polysaccharides of the tubercle bacillus or to protein-lipin complexes such as have been reported in serum. Perhaps a more decisive answer to this question, also, may be available when the next congress convenes.

If you will permit me I shall define "synthetic antigens" as "chemically altered antigens." We may then include such derivatives as the halogenated and nitro-proteins, which have been so useful in showing the importance of aromatic amino acids in serological specificity, and the acylated and phenylureido-derivatives which have also indicated the participation of the free ε-amino groups of the lysine component.

Preeminent among the synthetic antigens, however, are the azoproteins, which Landsteiner has used so fruitfully in tracing the delicate changes in specificity brought about by coupling proteins with one or another diazotized aromatic amine. That the original species specificity may, on occasion, disappear entirely, and be replaced by a specificity characteristic of the entering aromatic amine is a truly remarkable finding, and its exploitation has given us much that we know of the chemical basis of serological specificity. It was shown that position isomerism in the entering radicals causes a change in specificity, that the presence of an acidic grouping sharpens the new specificity and decreases cross reactivity, and di-, tri- and tetrapeptides have been coupled to protein by the same reaction and the influence of the arrangement of the individual amino acids traced. In Avery's laboratory sugars were most ingeniously coupled with proteins by the diazo reaction, and it was shown that the rotation of a single carbon atom in the entering group through an angle of 180°, as in glucose and galactose, produced a radical change in specificity. Moreover, it was possible to "reconstitute," as it were, the Type III pneumococcus antigen by coupling the pneumococcus specific polysaccharide to protein and showing that the antibodies produced on injecting this synthetic antigen into rabbits agglutinated Type III pneumococcus and protected mice against many lethal doses of the microorganism.

Azoproteins have also been most serviceable in testing the old Buchner hypothesis of antibody formation. Serum containing antibodies to arsanilic acid azoprotein contained no more arsenic than did the corresponding normal serum, indicating the failure of the specific determinant of the antigen to participate in the specific function of the antibody. Azoproteins have also served as useful reagents in the study of the mechanism of the precipitin reaction since, under special conditions, they permit the separate determination of antigen and antibody in specific precipitates of which the azoprotein forms a part.

If one attempts to penetrate more deeply into the reason for the change of specificity with change of the entering or hapten or determinant group in synthetic antigens one encounters immediate difficulties, some of which are possibly due to the vagaries of antibody formation in rabbits. Perhaps the most nearly successful correlation is with the "force fields" surrounding the molecular groupings in question, but agreement with the theory is scarcely more frequent than the exceptions, and some modification at the very least, appears necessary. Certainly it is to be expected that changes in serological specificity may be ultimately referred to changes, however minute, in chemical structure, even if the altered force fields resulting from such changes are not the operative causes.

A discussion of the structure of natural and synthetic antigens would scarcely be complete without a word as to the relation of antigenic structure to the antibody response in animals. This phase of the subject is somewhat complicated by the growing list of differences between antibodies engendered, for example, in the rabbit and in the horse, to which may be added the most recent finding, based on ultracentrifugal studies, indicating differences in molecular dimensions. Even if one neglects these differences until they have received more thorough study, one may still risk one or two generalizations.

Structural considerations indicate that the groupings responsible for serological specificity are repeated many times in the protein antigens and several times,

at least, in the specific polysaccharides. This structural peculiarity, or multivalence, is not shared by lipins, and this may possibly be a factor contributing to the difficulty of demonstrating antigenic properties in lipins. The multivalence of the antigens is not necessarily confined to a single serologically active grouping, but may readily be a property of several such groupings, so that it is not surprising to find that a single, crystalline antigenic substance, such as egg albumin, may give rise to more than one antibody, or even a whole series of antibodies. And since there is every evidence that these antibodies are modified serum globulins they also afford the opportunity of recurrence of serologically reactive groupings, or multivalence, so that antibodies, even to a single crystalline antigen, may differ both as to the number and character of their reactive groupings. These relationships are reflected not only in the wide range of combining proportions between antigen and antibody—often a tenfold one—shown by quantitative studies on the precipitin and agglutination reactions, but also by qualitative and quantitative differences in the reaction between antigen and fractionally absorbed or precipitated antibodies.

In conclusion, our knowledge of the structure of antigens, while still fragmentary, has at least progressed to the extent that we possess some knowledge of their chemical character and some inkling of the chemical differences between antigens which may be expected to give rise to differences in serological specificity. We are also beginning to acquire precise data on other chemical substances which we have hitherto designated rather vaguely as antibodies, and there would even appear to be certain advantages in considering the reactions between the chemical substances known as antigens and antibodies as chemical reactions, complicated, it is true, but subject to the same laws as simpler chemical systems. Our young science of immunochemistry has thus demonstrated its utility and promise as a powerful aid in the solution of many of the most puzzling problems both in biology and in immunity to infectious disease.

SCIENTIFIC EVENTS

THE NORWEGIAN MEDICAL ASSOCIATION, 1886–1936

THE jubilee of the Norwegian Medical Association is being celebrated this year. According to an account in *The British Medical Journal*, the secretary-general of the association, Dr. Jörgen H. Berner, has written its history in an imposing work of 353 pages, with portraits of the men who have played the most prominent parts in the life of the association since its foundation. During the fifty years under review the history of the association may be said to have been the history of the Norwegian medical profession and of Norwegian medicine. At the present time there are more than 2,100 doctors in Norway, and most of them are members of the association. Only a little more than a century ago, in 1816, there were exactly 100 medical men, of whom as many as twenty-eight were medical students. The number of practitioners enjoying the title of doctor of medicine was limited to twelve, whereas there were fifty-two surgeons. There was hardly any private practice in those days, most of the doctors being medical officers of health or in the employ of the army. By 1885 the number of Norwegian doctors exceeded 600. The *Journal* states that they lacked elbow-room, and that this was one of the motives for the establishment of a medical association which would keep discipline within the ranks and see to it that the overcrowding of the medical profession did not lead to a lowering of any of its standards. Another motive for the foundation of the association in 1886 was the revolt of the medical profession, its younger members in particular, against what seemed the reactionary attitude of the Faculty of Medicine in the capital. Medicine was splitting up into specialties, each of which created new educational demands, and the university teachers were unwilling or unable, probably both, to meet them. During the past fifty years the association has not only maintained discipline within, but has also generously shouldered its responsibilities in such important social problems as those of quackery, nursing, cancer and tuberculosis. The outstanding figure in the history of the association from 1898 to 1924 was Dr. Rasmus Hansson, secretary-general from 1900 to 1924. The present secretary-general, Dr. Berner, is also editor, jointly with Professor Carl Schiötz, of the association's journal, *Tidsskrift for den Norske Laegeforening*.

THE BRITISH PUBLIC HEALTH EXHIBITION

THE fifth British Public Health Exhibition was opened by the Minister of Health, Sir Kingsley Wood, at the Royal Agricultural Hall, Islington, on November 16. The exhibition is held in conjunction with the annual Public Health Congress.

One large group of exhibits was concerned with the work of hospitals for nervous and mental diseases. In the entrance hall was a collective display by manufacturers who have supplied apparatus and equipment for Runwell Hospital, the architects of which are Messrs. Elcock and Sutcliffe. This hospital will serve the needs of the county boroughs of East Ham and

Southend-on-Sea. It is built on the villa system, to accommodate 1,032 patients in nearly a score of separate buildings, and is claimed to be the most up-to-date hospital devoted to mental disease. The gallery of the Agricultural Hall gave a useful survey of what is being done for mental defectives by occupational therapy. The stands there displayed handwork of many kinds, the work of patients at mental institutions in different parts of the country.

The body of the hall was largely devoted to bulky motor vehicles, including new types of sweeping, refuse-collecting, watering and gully-emptying machinery such as are in use by the sanitary departments of municipalities. Demonstrations were given in the adjoining Gilbey Hall, which had been laid with a patent iron paving. To show that this paving is as effective a safeguard against skidding as any yet introduced, a motor-cycle combination was ridden with one wheel in the air, or driven from the side-car, or with the rider standing on the saddle, and so on. Among the motor transports on show there were also motor ambulances, and a piece of apparatus which at short notice can be attached to a municipal vehicle for spraying highways with anti-gas chemicals. The Department of Scientific and Industrial Research had a large exhibit to which about twenty research establishments contributed.

STUDY OF AIRPLANE VIBRATION AT NEW YORK UNIVERSITY

THE Daniel Guggenheim School of Aeronautics at New York University will make a detailed survey of airplane vibration and flutter in cooperation with the New York State Aviation Commission and the WPA.

It is planned to investigate the effect of high speeds on airplanes which test strong under slow speeds and have passed satisfactorily all static tests showing a high factor of safety, but which develop serious vibrations and flutter under increased speeds. These planes often cause grave accidents with the complete failure of the wing surface.

Dr. Alexander Klemin, director of the Guggenheim School; Professor Frederick Ketchman and Everett B. Schaefer will represent the university in this study, which will be participated in by twenty-five investigators. The project will involve:

1. A complete bibliography of literature on vibration and flutter, which will be published in many languages. Technical translators and research workers are being supplied by the WPA.

2. Equipment will be developed for experimental investigation of the subject, along with mathematical investigations.

3. Wings will be vibrated on the ground by means of a special vibrometer in order to study the characteristics while the surface is being disturbed by violent air forces.

4. In the large air tunnel of the university, carefullly designed and built models will be mounted to study flutter and oscillation under disturbed air conditions.

5. Equipment will be developed for the study of vibrations in actual flight with the cooperation of leading airplane construction companies, and plane operators, in the vicinity of New York City, and records will be made by mechanical and electrical pick-ups and by oscillographs, which will give actual flight conditions.

The work has also been endorsed by the New York City Commission of Docks, the Department of Commerce, and prominent construction firms. Engineers and mechanics will be assigned through the Works Projects Administration and will be under the supervision of New York University experts.

THE AMERICAN SOCIETY OF TROPICAL MEDICINE

THE thirty-second annual meeting of the American Society of Tropical Medicine was held in Baltimore from November 18 to 20.

Thirty-six papers were presented in five sessions, one of which was in conjunction with the National Malaria Committee. Officers elected for the ensuing year are: *President,* Dr. Herbert C. Clark; *President-elect,* Dr. Mark F. Boyd; *Vice-president,* Dr. Karl F. Meyer; *Councilors,* Major James S. Simmons, Dr. Robert A. Lambert and Dr. H. H. Anderson. Dr. N. Paul Hudson and Colonel Charles F. Craig were reelected to the offices of secretary-treasurer and editor of the journal, respectively.

The first awards of the Walter Reed Medal were made on November 19, at the luncheon of the society. Dr. Henry E. Meleney, president of the society, presided. The medal was conferred on Mrs. Walter Reed by Colonel Joseph F. Siler and received by her son, Major-General Walter L. Reed. In compliance with the condition of award to "an individual or an institution in recognition of meritorious achievement in tropical medicine," a second medal was awarded through Dr. Richard P. Strong to the Rockefeller Foundation for meritorious achievement in the study and control of yellow fever. It was accepted by Raymond B. Fosdick, president of the foundation. The committee of award was composed of former presidents of the society, Dr. Richard P. Strong, Colonel Joseph F. Siler and Admiral E. R. Stitt.

The Charles Franklin Craig Lecture in Tropical Medicine was inaugurated at the meeting. It was given by Dr. Ernest Muir, of London, the general and medical secretary of the British Empire Leprosy Relief Association. His topic was "The Control of Leprosy." Dr. Muir was a guest to the United States of the American Leprosy Foundation.

N. PAUL HUDSON,
Secretary

THE AMERICAN ACADEMY OF TROPICAL MEDICINE

THE third annual meeting of the American Academy of Tropical Medicine was held in Baltimore, on November 18, with President Richard P. Strong, of the Harvard Medical School, presiding. The academy has no scientific program, since it meets with the American Society of Tropical Medicine. At the annual dinner, at which members of the American Society of Tropical Medicine were guests, Dr. Robert Hegner, of the Johns Hopkins School of Hygiene and Public Health, presided as toastmaster. The guest speaker, Dr. Ernest Muir, was introduced by Perry Burgess, president of the Leonard Wood Memorial. Dr. Muir spoke on "Recent Progress in Tropical Medicine in India." The dinner program was concluded with an address by President Strong.

At the business session of the academy, Dr. Edmund V. Cowdry, professor of cytology at the Washington University Medical School, St. Louis, and Dr. Fred L. Soper, of the Division of International Health of the Rockefeller Foundation, were elected to active membership, and Professor W. A. P. Schüffner, of the School of Tropical Medicine, Amsterdam, was elected to honorary membership. The newly elected officers consist of: *President,* Dr. Wilbur A. Sawyer, Rockefeller Foundation, New York City; *Vice-president,* Dr. F. G. Novy, University of Michigan; *Secretary,* Dr. Ernest Carroll Faust, Tulane University; *Treasurer,* Dr. W. W. Cort, the Johns Hopkins University; *Councillors,* Dr. Herbert C. Clark, Gorgas Memorial Laboratory, Panama City; Dr. Thomas T. Mackie, New York City; Dr. Maurice C. Hall, National Institute of Health, Washington, D. C.; Dr. William H. Taliaferro, University of Chicago, and Dr. George C. Shattuck, Harvard Medical School.

ERNEST CARROLL FAUST,
Secretary

RECENT DEATHS

FRANK P. MCKIBBEN, consulting engineer, formerly professor of civil engineering at the Massachusetts Institute of Technology, Lehigh University and Union College, died on November 27 at the age of sixty-five years.

WILLIAM SAMUEL ROWLAND, chemical engineer, president of the Stanley Chemical Company, died on November 12. He was fifty-five years old.

DR. DAVID JUDSON LINGLE, physiologist, until his retirement in 1925 for thirty-three years a member of the faculty of the University of Chicago, died on November 27 at the age of seventy-three years.

DR. J. M. H. MUNRO died on November 6 at the age of eighty-one years. He was one of the founders in 1880 of the Downton Agricultural College in Wiltshire, England, and lectured on agricultural chemistry there.

Nature reports the death of Professor F. Hendrickx, emeritus professor of veterinary medicine in the Belgian Veterinary School, and of Dr. Gustaf Schack-Sommer, a pioneer in the sugar-beet industry in Great Britain, aged eighty-two years.

EDOUARD GOURSAT, professor of mathematics at the Sorbonne, Paris, and member of the Academy of Sciences, died on November 26 at the age of seventy-eight years.

SCIENTIFIC NOTES AND NEWS

THE John Fritz Gold Medal for 1937 has been awarded to Dr. Arthur Newell Talbot, professor emeritus of municipal and sanitary engineering in the University of Illinois. The medal is awarded for scientific achievement by a board composed of sixteen past presidents of the National Societies of Civil, Mining and Metallurgical, Mechanical and Electrical Engineers.

DR. EDWARD KASNER, professor of mathematics at Columbia University, has been awarded the Townsend Harris Medal of the College of the City of New York.

THE Chadwick Gold Medal and Prize for excellence in municipal engineering and hygiene has been presented to E. A. Drew, of University College, London.

THE Leonard Prize and Medal of the German Colloid Society has been awarded to Dr. Leo Ubbelohde, professor of applied chemistry in the University of Berlin.

A DINNER was held on October 19 in honor of Dr. John Harvey Kellogg, now eighty-four years old, on the completion of sixty years as head of the Battle Creek Sanitarium, Michigan.

HAROLD H. BEVERAGE, research engineer of R. C. A. Communications, Inc., a member of the board of editors of the *R. C. A. Review,* has been elected president of the American Institute of Radio Engineers.

DR. REGINALD FITZ, Wade professor of medicine at the Boston University School of Medicine and director of Evans Memorial Hospital, has been appointed lecturer in the history of medicine at Harvard University Medical School for three years. Dr. Fitz resigned in 1935 as associate professor of medicine at the medical school to go to Boston University.

DR. PAUL E. FIELDS, of Maryville College, Tenn.,

has become head of the department of psychology at the Ohio Wesleyan University.

H. E. GROSS, petroleum engineer in the Exploitation Department for the Shell Petroleum Company, Tulsa, Okla., for the past three years, has become a member of the faculty of the School of Petroleum Engineering of the University of Oklahoma.

DR. J. MARVIN WELLER, geologist and head of the Division of Paleontology and Stratigraphy of the Illinois Geological Survey, will teach, for the remainder of the semester, the courses in petroleum geology hitherto given by Professor Frank W. DeWolf, head of the department of geology and geography at the University of Illinois. Due to ill health Professor DeWolf will be absent from the university.

DR. WILLIAM MARSHALL SMART, John Couch Adams astronomer, chief assistant in the observatory and lecturer in mathematics at the University of Cambridge, has been appointed Regius professor of astronomy at the University of Glasgow in the place of Professor Ludwig Becker, who has retired.

Nature states that during the interregnum between the departure of Professor James Ritchie from the University of Aberdeen to the University of Edinburgh and the arrival of a successor, Professor Walter Garstang, formerly of the University of Leeds, will take charge of the department of natural history.

DR. FREDERICK SODDY has resigned from the chair of inorganic and physical chemistry at the University of Oxford, which he has held since 1919.

DR. CHARLES-EDOUARD GUILLAUME, director of the International Bureau of Weights and Measures, Paris, has retired after serving for fifty-three years. He will be succeeded by M. Albert Pérard, assistant director of the bureau.

HERBERT K. ALBER, instructor in chemistry at New York University, has become research microanalyst at the Biochemical Research Foundation of the Franklin Institute, Philadelphia.

L. S. KASSEL, for the past five years physical chemist in the U. S. Bureau of Mines, has been appointed research engineer of the Universal Oil Products Company.

DR. PERCY M. BARR, formerly chief of the Research Branch of the British Columbia Forest Service, who has been for the last four years a member of the Division of Forestry of the University of California, has leave of absence during the present semester to aid in a general reorganization of the department of forestry of the University of British Columbia.

DR. CARL ANDERSON, of the California Institute of Technology, left on November 30 to attend the ceremonies at Stockholm to receive the Nobel prize in physics that has been awarded to him. He will give an address on his work.

NORMAN B. TINDAL, ethnologist in the South Australia Museum at Adelaide, is visiting the United States.

DR. VLADIMIR KARAPETOFF, professor of electrical engineering at Cornell University, who recently was granted a patent on his invention of an electrical distribution system, has assigned the patent rights to the General Electric Company, Schenectady.

THE New York *Herald-Tribune* reports that Viacheslav Volgin, geologist, and Nikolai Bukharin, publicist, members of the Academy of Science at Leningrad, have been asked to appear before the Communist party organization to explain how they happened to allow "Trotskyist Fascist" tendencies to develop in the academy.

AT a meeting of the Board of Trustees of the American Museum of Natural History on November 9, Charles Hayden, member of the firm of Hayden, Stone and Company, was elected a member of the board. Mr. Hayden gave the sum of $100,000 toward the erection of the Zeiss projector and the solar system exhibit in the planetarium, which was named the Hayden Planetarium in his honor. At the same meeting a committee was appointed by the board to cooperate with other groups in preparation for the forthcoming World's Fair to be held in New York City. The committee consists of Frederick Warburg, *chairman;* Charles Hayden, Arthur S. Vernay, Douglas Burden, Clarence L. Hay, Junius S. Morgan, Dr. Roy Chapman Andrews and F. Trubee Davison.

DR. R. W. WOOD, of the Johns Hopkins University, will give three Christmas week lectures for young people of the James Mapes Dodge Foundation of the Franklin Institute, Philadelphia, on December 28, 29 and 30. The subject of the lectures is "Crystal Magic." Dr. Wood gave ten years ago the first series of lectures on this foundation.

DR. ERNEST W. GOODPASTURE, professor of pathology at the School of Medicine of Vanderbilt University, will deliver the thirteenth Ludvig Hektoen Lecture of the Frank Billings Foundation on January 22. His subject will be "Vaccinia."

PROFESSOR DOUGLAS JOHNSON, of Columbia University, delivered the annual fall lecture of the Department of Geology and Geography at Syracuse University on November 11. In the afternoon he addressed the advanced students of the department on "The

Correlation of Coastal Terraces," and in the evening before a general audience spoke on the "Evolution of the Grand Canyon District."

DR. ARTHUR C. CHRISTIE, formerly professor of radiology at the George Washington University Medical School and at Georgetown University, delivered the Silvanus Thompson Lecture before the British Institute of Radiology at its annual congress in London on December 2.

SIR FRANK SMITH, secretary of the Royal Society and secretary of the Department of Scientific and Industrial Research, delivered the first Parsons Memorial Lecture before the North-East Coast Institution of Engineers and Shipbuilders on November 6. Arrangements for honoring the memory of Sir Charles Parsons, who died in 1931, have been made by the Royal Society. They take three forms—a memorial in Westminster Abbey, a Memorial Library in London House and an annual lecture, which is to be delivered every fourth year on the North-East Coast, the other lectures being in London.

A MEETING of the American Shore and Beach Preservation Association, under the presidency of J. Spencer Smith, of Newark, N. J., will be held on December 14 in Washington, under the auspices of the National Research Council.

BY the will of the late Dr. Edward Weston, who died on August 20 at the age of eighty-six years, the Newark College of Engineering will receive his scientific library of more than fifteen thousand volumes, together with his early electrical apparatus and drawings. The will also provides sufficient funds for the housing and maintenance of the library.

GIFTS amounting approximately to $90,000 have been announced by the Yale Corporation. These include $28,333 from the Rockefeller Foundation for varied research and $16,376 for the Edward R. Pidgeon Fund for general purposes.

LORD NUFFIELD, chairman of Morris Motors, Ltd., has added £750,000 to his recent gift to the University of Oxford, making the total sum £2,000,000. His original gift was insufficient for full development of the medical school on the lines he had intended.

THE London *Times* reports a bequest of £20,000 by the late Edith Mary Valentine Scott Lang to St. Andrews University, Scotland, for a Napier lectureship in astronomy in memory of Baron Napier of Merchiston. The bequest is subject to the condition that the university provides an observatory and instruments. Miss Lang's father, Sir Peter Redford Scott Lang, was regius professor of mathematics at St. Andrews for forty-two years.

The New York Times states that a center to include a permanent museum of health and hygiene is planned for the World Fair of 1939. The Oberlaender Foundation and the Carnegie Corporation have pledged financial assistance, and other grants will be sought. Dr. Louis I. Dublin, chairman of the advisory group which will formulate plans for the buildings and exhibits, has sailed for Europe, where he will seek to interest health and hygiene organizations in meeting in New York during the fair. Dr. James R. Reuling is vice-chairman of the committee and Homer N. Calver is secretary. Health Commissioner John L. Rice and Hospitals Commissioner S. S. Goldwater represent the city. Medical groups are represented by Dr. George Baehr, of the New York Academy of Medicine, and Dr. Reuling, of the American Academy of Medicine. Public health groups are represented by Dr. Victor Heiser, chairman of the General Council on Medicine and Public Health; Dr. Dublin, of the National Health Council, and Mr. Calver, of the American Public Health Association. The committee will be increased later. A museum patterned after the Museum of Hygiene in Dresden, Germany, is planned, also a complete health and medical exhibit, a model health village, use of safety devices and services throughout the fair for the benefit of visitors and control of all products sold or promoted on a health basis.

A NEW six-hourly system of reports of the U. S. Weather Bureau is expected to be in operation by January 1. About thirty of these stations will be established at existing first order Weather Bureau stations and ninety new stations will be located geographically so as to give a fairly well-spaced and dense network of reports over the entire country. These stations are intended primarily to facilitate the preparation and improve the accuracy of six-hourly airway forecasts by use of the methods of air-mass analysis. Full instrumental equipment, including an anemometer, mercurial barometer and an open-scale barograph will be supplied to all new stations. The new station on the summit of Mt. Mitchell, N. C. (6,639 ft. M.S.L.), provides a mountain observatory station in the southeastern United States similar to Mt. Washington, N. H., in the northeastern United States. A national distribution will be given to all six-hourly reports, except that reports from the new stations in the far eastern or western portions of the country will be given distribution only to local districts concerned.

Museum News states that the Boston Society of Natural History has named its museum the New England Museum of Natural History; and is making alterations in its building and rearranging its exhibits with the view of making the museum more attractive to the public. A huge stair-well in the

center of the building connecting the main and second floors is being eliminated. New stairways are being constructed on either side, leaving the central space free for exhibits. The main entrance hall will have new cases for changing exhibits and at the back, opposite the front door, a group of herring gulls and common terns on sand dunes at Plymouth harbor. The lecture room floor is being leveled so that the room can be used for children's work also. A new room for study collections is provided in the basement. Exhibits are being rearranged by all the departments with the idea of appealing to the public rather than of adhering to the purely scientific point of view. Herpetological exhibits, for instance, will emphasize life histories and economic value of reptiles and amphibians; birds are grouped by habitat and status as residents. New labels to interest the visitor are being worked out. The museum is closed while alterations are being made. The date for the reopening of the building has not yet been set, but it will probably be early in the coming year.

A COLLECTION of several hundred Californian plants which has all but encircled the earth is now being studied in the herbarium of the California Academy of Sciences in San Francisco. The specimens were collected in 1840 and 1841 by the Russians in the region then known as Russian California ("California boreal. Ross." the labels read) and were sent from California to the herbarium of the Russian Academy in St. Petersburg by way of Vladivostok and across Siberia. These same specimens which have remained unnamed for nearly a hundred years are being determined by J. T. Howell at the California Academy of Sciences after which they will be returned to the herbarium of the Academy of Sciences in Leningrad. The plants, which were collected in different parts of the Russian territory, were obtained by Vosnesensky ("Wosnessensky"), who was in the first party to climb Mt. St. Helena in the Californian Coast Ranges north of San Francisco. Fort Ross, the chief Russian port and settlement on the Californian coast, is about sixty miles north of San Francisco.

DISCUSSION

LENS-LIKE ACTION OF A STAR BY THE DEVIATION OF LIGHT IN THE GRAVITATIONAL FIELD

SOME time ago, R. W. Mandl paid me a visit and asked me to publish the results of a little calculation, which I had made at his request. This note complies with his wish.

The light coming from a star A traverses the gravitational field of another star B, whose radius is R_o. Let there be an observer at a distance D from B and at a distance x, small compared with D, from the extended central line $\overline{AB}$. According to the general theory of relativity, let α_o be the deviation of the light ray passing the star B at a distance R_o from its center.

For the sake of simplicity, let us assume that $\overline{AB}$ is large, compared with the distance D of the observer from the deviating star B. We also neglect the eclipse (geometrical obscuration) by the star B, which indeed is negligible in all practically important cases. To permit this, D has to be very large compared to the radius R_o of the deviating star.

It follows from the law of deviation that an observer situated exactly on the extension of the central line $\overline{AB}$ will perceive, instead of a point-like star A, a luminius circle of the angular radius β around the center of B, where

$$\beta = \sqrt{\alpha_o \frac{R_o}{D}}.$$

It should be noted that this angular diameter β does not decrease like $1/D$, but like $1/\sqrt{D}$, as the distance D increases.

Of course, there is no hope of observing this phenomenon directly. First, we shall scarcely ever approach closely enough to such a central line. Second, the angle β will defy the resolving power of our instruments. For, α_o being of the order of magnitude of one second of arc, the angle R_o/D, under which the deviating star B is seen, is much smaller. Therefore, the light coming from the luminous circle can not be distinguished by an observer as geometrically different from that coming from the star B, but simply will manifest itself as increased apparent brightness of B.

The same will happen, if the observer is situated at a small distance x from the extended central line $\overline{AB}$. But then the observer will see A as two point-like light-sources, which are deviated from the true geometrical position of A by the angle β, approximately.

The apparent brightness of A will be increased by the lens-like action of the gravitational field of B in the ratio q. This q will be considerably larger than unity only if x is so small that the observed positions of A and B coincide, within the resolving power of our instruments. Simple geometric considerations lead to the expression

$$q = \frac{l}{x} \cdot \frac{1 + \frac{x^2}{2l^2}}{\sqrt{1 + \frac{x^2}{4l^2}}},$$

where

$$l = \sqrt{\alpha_o D R_o}.$$

If we are interested mainly in the case $q \gg 1$, the formula

$$q = \frac{l}{x}$$

is a sufficient approximation, since $\frac{x^2}{l^2}$ may be neglected. Even in the most favorable cases the length l is only a few light-seconds, and x must be small compared with this, if an appreciable increase of the apparent brightness of A is to be produced by the lens-like action of B.

Therefore, there is no great chance of observing this phenomenon, even if dazzling by the light of the much nearer star B is disregarded. This apparent amplification of q by the lens-like action of the star B is a most curious effect, not so much for its becoming infinite, with x vanishing, but since with increasing distance D of the observer not only does it not decrease, but even increases proportionally to $\sqrt{D}$.

ALBERT EINSTEIN

INSTITUTE FOR ADVANCED STUDY,
PRINCETON, N. J.

PLEISTOCENE MAN IN SOUTHERN CALIFORNIA

ON the twenty-third of January of this year the Federal PWA Project, C-642, in an excavation project to build a storm drain from Los Angeles to the sea, unearthed what has proved to be a very interesting and doubtless significant discovery of early man in America. The chief engineer, Mr. J. J. Ryan, of the project, called the department of anthropology of the University of Southern California, Los Angeles, asking that some one be sent out to the excavation to examine some bones thought to be human which had been unearthed on Rancho Cienga O'Paso de la Tijera. Dr. Bowden, head of the department, and Dr. Lopatin, instructor in anthropology, went out and examined the discovery. A skull and other human bones were recovered from a gray sandy clay resting immediately upon the gravel some thirteen feet below the surface. Dr. Lopatin was left in charge for about ten days until all clues for possible cultural material had been examined. With the help of workers from the project an area of about 20 feet was carefully excavated under his direction.

It is thought that these bones and skull belonged to the same human being, since they were found together and since the deposit was altogether undisturbed, but there was no trace of burial. The skull and bones had evidently been covered with sandy clay by river deposits. The thirteen feet of clay was made up of five strata which were clearly distinguishable, since the storm drain runs in an east-west direction along what is probably the old bed of the Los Angeles River, the trench thus providing a splendid cross-section of the strata. All the deposits on the walls of this trench appear to be fairly well bedded, and even to a casual observer they are very clear. The strata run almost horizontally, thus making them easy to trace for hundreds of feet. Over these skeletal remains were four strata. Beginning at bottom the stratum was gravel, about four feet thick. Over that was a gray clay two feet thick, which covered the human remains; then three feet of very dark clay. The fourth stratum from the bottom was gray clay, three to four feet thick, with boulders enmeshed. The top stratum was three feet of yellow clay; no loam soil on top.

For several weeks the site was watched by Dr. Lopatin and the workers, with the hope that other discoveries of the kind would be made, and on the thirteenth of March about one thousand feet from the site where the human remains were found, several bones of a large animal were discovered. Four large teeth and some fragments of tusks came to light in close proximity to the large bones. For identification, Dr. Thomas Clements, of the geology department of the University of Southern California, was called in consultation. He identified these bones as those of the mammoth (*Archidiskodon imperator* Leidy).

Due to the extended and thorough excavation of the government project a thorough examination of the stratification could be made, and it was found that the mammoth bones were in the same stratum as that of the human remains and were covered to a depth of about 12 feet. Likewise there were five strata involved. The bottom, where the mammoth bones were imbedded, was that of gravel with sand about two feet thick. The next was yellow clay one foot thick. Overlying this was about two feet of black clay; then, less than two feet of peat of good quality. The top stratum was black soil seven feet thick.

The fact that the human bones and those of the mammoth were found in the same geological stratum enabled us to conclude that both the man and mammoth had lived at approximately the same time, *i.e.*, at the closing of the Pleistocene Epoch. Dr. Clements, after thorough examination of the complete stratification and environment, concluded that the geological stratification indicated Pleistocene strata.

All the bones, both of the human and the mammoth, were in a high state of complete fossilization and heavily coated with rock (sandstone and conglomerate). The human skull is badly damaged, lacking the entire facial part; only the posterior portion of the calvaria, or the brain box, is present. The skull is small in size. Judging from the state of the sutures of the cranium vault as well as from its small size and the smoothness of the external surface of the bones, the authors of this article came to the conclusion that the skull was that of a female well advanced in years. For the sake of

brevity the find will be called in this paper the Los Angeles skull.

In comparing this skull with other female skulls found in America it is seen that in breadth (132 mm) and in basion-bregma height (131 mm) it is rather close to the "Basket Maker" cranium. The height-breadth index of the Los Angeles skull is considerable —99.24; therefore, it should be classified as acro-cranial. On account of the damaged state of the Los Angeles skull it can not be measured as to maximum length, but in all probability the skull is dolicho-cephalic.

The index of the foramen magnum of the Los Angeles cranium is very high—96.7. Thus, although the size of the occipital foramen is small, yet in its shape it is very broad.

The maximum thickness of the walls of the brain case of the Los Angeles cranium is rather considerable —7 mm. In the Calaveras skull it is 8 mm.

Since all the facial skeleton is lacking it is very difficult to conceive clearly the physical type of the individual. The cranium exhibits no striking primitive features which would justify classification of its owner as a lower being. On the contrary, the brain box is decidedly human, and the individual is a representative of our species.

A. O. BOWDEN
IVAN A. LOPATIN
UNIVERSITY OF SOUTHERN CALIFORNIA

FOSSIL LEAVES OF DICOTYLEDONOUS FLOWERING PLANTS

I WISH to make a preliminary announcement in SCIENCE of the discovery of fossil leaves of dicotyledonous flowering plants in formations of the Trinity division of the Comanchean, in Erath County, Texas. The most striking features of these leaves are first, their already highly organized structure, and next, their remarkable variability, no two specimens being closely similar.

The full description of the new finds is being prepared for publication.

O. M. BALL
AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

SCIENTIFIC BOOKS

GEOGRAPHY OF DISEASE

A Geography of Disease. A Preliminary Survey of the Incidence and Distribution of Tropical and Other Diseases. By EARL BALDWIN MCKINLEY, M.D. Published as a Supplement to the *American Journal of Tropical Medicine.* Pp. i + xxv, 1–495. George Washington University Press, Washington, D. C. 1935.

THIS valuable study of the geography of disease was made possible by a grant from the American Leprosy Foundation (formerly the Leonard Wood Memorial) to the Division of Medical Sciences of the National Research Council, and was prepared from collected data by Dr. McKinley, the director of studies, assisted by an advisory committee consisting of Drs. Frederick P. Gay, Richard P. Strong and the late Theobald Smith. In his introductory chapter Dr. McKinley well says that "the geography of disease has never been written and the exact picture of this important subject, of such deep significance to mankind, may never be painted," but this volume certainly adds greatly to our knowledge and is an excellent stepping-stone toward a more complete recording and understanding of the distribution of disease.

In the collection of the data contained in this book, special stress was laid on the geographical distribution of tropical disease, so that the work is of special interest and value to those interested in diseases occurring in warm countries. It is not necessary to emphasize the importance of the geographical distribution of disease, but unfortunately the subject appears to have attracted little attention, and this is the first contribution to it that has appeared in many years. The geographical distribution of disease in each country is considered separately, and valuable tables summarizing disease distribution in each country are given at the end of the section treating of the country in question. It is evident that there is great lack of uniformity and accuracy in the statistics of disease as furnished by the various health departments consulted. This is especially evident regarding the reports of local and state boards of health in this country when compared with the reports of foreign countries, and this book is valuable in that it calls attention to this lack of accuracy in our health statistics. For instance, in the distribution of malaria as reported by various health authorities, it is noted that it is impossible to arrive at any adequate conception of the incidence of the various types of malaria in this country, since only two states, Alabama and Kentucky, furnish any data relative to the respective incidence of tertian, quartan and estivo-autumnal malaria. On the other hand, these data are available for most foreign countries.

The volume contains special chapters upon the most important tropical diseases, malaria being considered by Boyd; bacillary dysentery by Strong; amebiasis by Craig; typhoid fever by Gay; tuberculosis by White; Brucellosis by Evans; dengue fever by Siler; yellow

fever by Sawyer; typhus fever by Dyer; leprosy by McCoy; syphilis by Chesney; yaws by Butler; trachoma by Julianelle; tularemia by Francis; clonorchiasis by Strong; schistosomiasis by Faust; filariasis by O'Connor; beri-beri by Vedder; malnutrition and undernutrition by Cook; and chemotherapy by Leake. These special discussions add much to the scientific worth of the book and include short but excellent presentations of the distribution of the various diseases considered.

The labor involved in the collation of the data furnished in this work can be realized only by one who has edited similar publications, and the author is to be congratulated upon a volume which should prove of great value to all public health officers and to all who are interested in the geography of disease. As already stated, the book is of special interest to workers in tropical medicine. The medical profession and the sanitarian owe Dr. McKinley a debt of gratitude for having made available for the first time in many years a real geography of disease.

CHAS. F. CRAIG

TULANE UNIVERSITY

ASTRONOMY

The Realm of the Nebulae. By EDWIN HUBBLE. xiii and 207 pp., 1936, $3.00. New Haven: Yale University Press.

Two outstanding characteristics of this account of the Metagalaxy are the wealth of scientific material involved and the breadth of outlook. There are minute and frequently technical descriptions of the steps needed to establish, for example, the distances of the nebulae, or the magnitude effect of the red shift, or the velocity-distance relation. But we do not lose sight of the fact that the goal is an integrated picture. We are shown exactly why each separate problem is raised. The forest remains in sight, despite the trees.

One could wish that, for the sake of the scientist more than for the layman, some of the researches were more fully discussed. The consideration of uniform distribution of nebulae seems to be left in a tentative state; concentrations within clusters certainly must have a more direct bearing on both practical and theoretical problems than the author indicates. A mystery still rests also in the calibration of the velocity-distance relation. The coefficient derived on the basis of the brightest stars in nebulae is almost exactly that derived previously from the mean absolute magnitude of the galaxies. But, curiously enough, the mean absolute magnitude is now found to be 0.4 magnitudes brighter than before. We may hope that detailed publication of the work involved will explain the apparent inconsistency.

Such criticism, however, is a matter of detail. The importance of the work lies in the clarity and fulness of its account of a complex scientific problem. The style is smooth and clear; the author's habit of referring to the same subject in different contexts tends to unify the work. The material is both inciting and exciting, and the volume is a valuable contribution to knowledge of the Cosmos. J. M.

Theoretical Astrophysics. By S. ROSSELAND. Oxford: The Clarendon Press, 1936. Pp. xix + 355. Figs. 47. $8.00.

THE study of astronomy is handicapped by the scarcity of satisfactory texts, and this has been especially true in the field of theoretical astrophysics. Therefore the appearance of "Theoretical Astrophysics," by S. Rosseland, is an event very much to be welcomed—the only complete modern treatise on astrophysics (with the exception of the same author's "Grundlagen der Astrophysik"). The author is professor of astronomy at the University Observatory, Oslo, and director of the Institute of Theoretical Astrophysics, and is well known for his contributions to the fields covered in this treatise.

For about a third of the book, astronomy is not considered at all, while Professor Rosseland presents the fundamental ideas of quantum physics, beginning with the classical equations of analytical dynamics and statistical mechanics. The object here is to give the student a self-contained and logical development—including the Schrödinger equation and its application to a few elementary problems, simple spectra, the periodic system, complex spectra and the theory of absorption and emission of radiation. With few exceptions, the methods of quantum mechanics are adhered to, and while they are condensed and clarified remarkably (104 pages), the reader feels that he has a working outline of theoretical physics and a background from which he can proceed to astrophysics, or to further work in theoretical physics, with confidence. Discussions of certain additional topics in physics—such as the Zeeman and Stark effects, and molecular spectra—are included in the corresponding applications to stellar atmospheres.

The remainder of the book takes us from the analysis of normal stellar atmospheres to extended atmospheres, nebulae and interstellar gases. Professor Rosseland states in the preface that his aim is the formulation of a program of theoretical astrophysics. This is accomplished by detailed critical reports on important researches of the past few years and by the accompanying theoretical exposition of methods.

A considerable amount of attention is necessarily devoted to the equations of the transfer of radiation, leading to the interpretation of the continuous spectrum and the profiles and intensities of absorption

lines, in normal stars, and then the special cases of expanding and rotating stars. These chapters on a subject which especially needed to be brought up to date and set in order, are particularly valuable. In addition ample space is given to the increasingly important study of band spectra and dissociative equilibrium of stellar compounds.

The chapters on stars with extensive envelopes and on nebulae are also worthy of being mentioned separately, for they include the interpretation of Wolf-Rayet stars and novae as stars which are continually ejecting matter, the new developments in the identification of lines arising from forbidden transitions and the explanation of nebular bright lines in terms of Rosseland's theory of cycles.

Both the student and the experienced astronomer will find this book a necessity for their libraries. For the former it provides a remarkably complete system of modern theoretical physics and its astrophysical application. The latter will find in it a coordinated picture of stellar atmospheres and the methods of analysis heretofore available only in piecemeal. It is a pleasure to know that "a second volume is planned to give a similar view of the internal structure of stars, analyzed in terms of nuclear physics and hydrodynamics." C. J. A. R.

REPORTS

THE WORK OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

EXPANSION of educational activities and enlargement of faciiities for student welfare calling for a fund of $12,500,000 were proposed in a program of objectives presented by Dr. Karl T. Compton, president of the Massachusetts Institute of Technology, at the autumn meeting of the corporation on October 14.

The program of development outlined by Dr. Compton will require a capital expenditure of $2,750,000 for new buildings and equipment and a capital fund of $9,750,000 to produce an annual income of approximately $390,000.

The major objectives of the plan, which will be brought to fulfilment as soon as possible, include a new dormitory to house 100 students; a large gymnasium or an addition to Walker Memorial, the student recreation center; a biological engineering laboratory; funds for research and fellowships, extension of the institute's high voltage research projects; a new aeronautical wind tunnel and a naval towing tank.

Expressing his belief that the country is now in a period of transition from depression to at least relative prosperity, Dr. Compton said:

> We should now pay active attention to the needs and opportunities with which we find ourselves confronted—needs and opportunities which have in part been disclosed by our intensive study in the past few years, in part have arisen through progress in science and engineering, and in part have sprung from the creative work of our own staff. Some of these opportunities show such promise that their neglect would be no less than educational sabotage.

Speaking of the increasing emphasis on graduate work and research as reasons for new facilities, he said that "graduate work in engineering was almost negligible in the period before the erection of our present educational plant. Graduate work in science did exist but only to a small fraction of its present importance. The plant, conceived as it was with great generosity and remarkable vision, and in spite of additions, has nevertheless become inadequate to the demands now made upon it by increased enrolment, graduate work and research."

The need for a more adequate development of Technology's research program was emphasized by Dr. Compton.

> No educational institution in my knowledge has ever approached its possibilities for contributing to public welfare by giving attention to the efficiency of its research program comparable to that which it gives to its teaching. No institution has such great possibilities in this direction as the Massachusetts Institute of Technology. I can imagine no investment for public welfare so likely to secure large returns as one which would permit the latent creative powers of this institution to become really active.
>
> If the Massachusetts Institute of Technology will really grapple with the opportunity here outlined, it will perform a new order of public service along the lines of its charter, which directs it to "aid generally by suitable means the advancement, development and practical application of science in connection with arts, agriculture, manufactures and commerce."

Dr. Compton's proposals were submitted to the corporation with his annual report in which he reviewed the operation of the institute in the past year and the successful solution of the many economic problems confronting educational institutions during the depression. In setting forth his proposals for the future, he divided the program into two parts, one dealing with educational activities and the other with student welfare.

STUDENT WELFARE

Outlining the urgent need for additional housing accommodations, he directed attention to the fact that there is a present unsatisfied demand for rooms for at

least 200 graduate and undergraduate students and added that the demand is likely to increase. He proposed as a beginning to erect a dormitory accommodating 100 students at a cost of approximately $500,000.

Turning to recreational and extra-curricular activities, the institute's president spoke of the lack of adequate facilities for recreation. With the institute's emphasis on recreational sports rather than highly financed and organized athletics, such facilities are especially necessary. The advantages of a large gymnasium, he said, would include its use as an auditorium. A new building would release the present inadequate gymnasium in Walker Memorial for use as a student theater and office space. The cost of such a project, he estimated, would be approximately $1,000,000. He suggests that a study be made to determine whether a gymnasium or an addition to Walker Memorial is the more desirable.

Fellowships

Dr. Compton called for $60,000 a year for additional fellowships, which he said should be considered primarily as prizes and incentives or as providing opportunity for study and investigation of problems of exceptional interest.

These funds would be used for four classes of fellowships. One would be to assist graduate students who now do part-time teaching while working for advanced degrees. Under this plan they often have to spend from five to six years to complete their work. The new fellowships would make it possible to relieve promising men of some of the burden of earning their way in the last year of graduate work.

A second fellowship is desired for students who, having taken their graduate degrees, are engaged on research projects worthy of further investigation. This type of fellowship would permit a student to continue important research work a year after receiving his degree.

Still another class of fellowship is desired to extend and place on a more permanent basis the system of honorary sponsored fellowships which has been given a decidedly successful trial on a small scale in the department of business and engineering administration. Two ideas are basic to these fellowships, the one having to do with the selection of the fellows, and the other with the educational program made available to them. The fellows are selected from business and industrial organizations with cooperation of the management, and are preferably from two to five years out of college. Thus an exceedingly promising young employee is given leave of absence for one year by his employer in order to carry on, under the fellowship, advanced study of business and engineering administration leading to a master's degree at the institute.

This plan carries into the training of young men for business positions something of the same advantageous experience gained by the young doctor or the young lawyer in his period of interneship or apprenticeship, when he has opportunity to observe the work of the best men in his profession. Hitherto such an advantage has not been given the young apprentice in a business organization, since he commonly comes early into contact only with the lowest grade of business executive. The experience of the small group of honorary fellows during the past five years and their very remarkable record of success immediately following their fellowship year are ample evidence of the soundness of this educational program. Funds for the fellowships are essential, however, since the young men who can best benefit by this program are in general unable at this critical stage in their careers to make the combined sacrifice or loss of earnings for a year and payment of tuition.

The fourth type of fellowship would supplement the institute's undergraduate scholarship and loan plan, and would be awarded as scholarship aid to students in their senior year.

Aeronautical Engineering

The remarkable progress of aeronautical engineering in recent years was indicated in Dr. Compton's report by the statement that airplane speeds have increased so rapidly that the institute's big wind tunnel, built in 1923, is now inadequate for the purpose for which it was designed. He said:

> The Institute had the first course in aeronautical engineering in America, and the first wind tunnel. It has a notable record of achievement and an able staff. Lack of this modern facility should not be allowed to relegate the department to a less effective position. A unique design of wind tunnel is planned, which will gain the advantages of a very large tunnel with enormous wind velocity through the expedient of operating at an adjustable air pressure within the tunnel. By this means the cost of a satisfactory tunnel can be brought down to $125,000.

Towing Tank

In a somewhat analogous category with the wind tunnel is the need of a model towing tank for the department of naval architecture and marine engineering. This has long been a subject of intense interest to the institute, dating back at least to the time when the late President Stratton and John R. Freeman made intensive studies and preparations for the installation of a combined hydraulic laboratory and towing tank. Unfortunately circumstances have thus far prevented the consummation of their well-laid plans.

Much of the most valuable work on hull design of ships and in the scientific study of the phenomena of ships afloat has been done with the aid of towing tanks which

are much smaller and less expensive than the tank originally projected for the institute. Encouraged by this fact, and convinced that a department of naval architecture and marine engineering so prominent as the institute's should not be handicapped by lack of this essential piece of equipment for teaching and research, favorable consideration has recently been given to the advantages which would be offered by a small tank costing perhaps $35,000.

In view of the institute's increased responsibility in the training of naval constructors, who now spend all three years of their post-graduate work at the institute, and in view of the general tendency to give more scientific attention to ship design, I recommend that steps be taken to provide a naval towing tank.

High Voltage Laboratory

Significant opportunities would be opened up in our teaching and research program by the provision of suitable facilities for experimental and developmental work in the field of high voltage electricity. In this, both the electrical engineering and physics departments are intensely interested.

There are definite industrial trends toward the use of even higher voltage; there are many important practical problems to be solved and a great virgin field for scientific and industrial pioneering. The physicist is especially interested in the use of high voltage to explore the inner nuclei of atoms, those tiny citadels which for centuries withstood the efforts of the alchemists.

This new field may well prove to be as far-reaching in its scientific and practical influence as were those which were opened up by the discovery of the electron a century ago. The institute is now in the unique position of having on its staff probably the most competent men in the world in fundamental aspects of the high voltage field, and it is also in the position of having developed the equipment for producing direct current of ten times higher voltage than any which have hitherto been achieved. All this opens up a very large field for research and for thesis work by graduate students, provided the necessary facilities can be secured.

It appears that a reasonably active prosecution of this program will require the construction of some $340,000 worth of buildings and equipment, and an annual operating budget of $50,000, or the income from $1,250,000. This figure, while large, is exceedingly small in relation to the value of some of the industrial possibilities in the high voltage program.

Biological Engineering

Prospects of future developments of great importance in the field of biological engineering involving a carefully planned approach to biological and medical problems, and calling for the cooperative efforts of biologists, physicists, chemists and engineers, were indicated in Dr. Compton's plan for a new laboratory building to house the department of biology and public health. The cost of the building he estimated would be approximately $750,000, and an annual fund of $80,000 would be required for its satisfactory operation.

After reviewing the work of the department, which has made many important and pioneering contributions in the field of public health, food technology and medicine, Dr. Compton outlined some of the opportunities for advances in the new field of biological engineering through combined cooperative research in various branches of science and engineering. Citing the results of cooperative projects already undertaken at the institute, he said:

> It has been generally agreed by scientists that the biophysical and biochemical approach to biological and medical problems is one which offers tremendous possibilities. In fact it is probable that this line of approach is the one most likely to lead to a fundamental understanding of the complex problems here involved. I believe that there is much promise in a type of approach to applied biology which could be carried out in the environment of the Institute, with its biology department free to call for advice on a wider variety of scientific and engineering specialists than can be found in any other institution.

Research Funds

The greatest need of the institute, Dr. Compton told the corporation, is at least $200,000 annually or a capital endowment of $5,000,000 for important research.

Types of research which would be possible if funds are provided might include, he said, such important investigations as the effects of low temperatures, the production of powerful magnetic fields, concrete construction, housing, meteorology and development of new uses for agricultural products.

> These are only a few outstanding examples of the needs and opportunities in the institute's research program. They are projects which may well involve considerable groups of men. In addition, however, there are many other such group programs, as well as individual investigations. Every graduating senior, every candidate for a master's degree, every candidate for a doctor's degree, carries on some type of investigation. The increasing importance and the great educational value of all this work is my reason for placing a fluid research fund at the forefront of the larger program.

In the course of his formal report to the corporation on the operation of the institute during the past year Dr. Compton reported an increase of more than $15,000 in investment income and student fees over the preceding year, bringing the total operating budget to $2,714,301. Capital and miscellaneous gifts amounted to $429,533. The institute closed its year with a small balance of less than $5,000, which was applied to reduce the cumulative deficit. The market value of endowment funds increased during the year from $32,562,000 to $36,530,000.

SPECIAL ARTICLES

THE ULTRACENTRIFUGAL CRYSTALLIZATION OF TOBACCO MOSAIC VIRUS PROTEIN

WHEN the clear juice pressed from plants[1] infected with tobacco mosaic virus is centrifuged at 25,000 r.p.m. (maximum field = 40,000 gravity), a pellet separates at the bottom of the tube. Under the polarizing microscope this solid is obviously crystalline. Tests show it to contain all but a small fraction of a per cent. of the virus initially present in the juice; we have accordingly sought to determine whether such crystals, obtained by high-speed centrifuging, are the same as those of the chemically[2] prepared virus protein.

One of the most distinctive characteristics of a crystalline species is its x-ray diffraction pattern. That of the chemically purified virus protein is known[3] to be well defined and to consist of many sharp lines. The x-ray method has therefore been chosen to compare the crystals made chemically and by ultracentrifugal precipitation. To do this, 5 cc portions (1) of plant juice clarified by filtration through Hyflo Supercel followed by freezing and a subsequent low-speed centrifuging and (2) of solutions of the chemically purified virus protein were centrifuged for three hours in an air-driven ultracentrifuge.[4] The quantity head containing the tubes of liquid resembled one recently described[5]; it had previously been used for the concentration of pneumococcic antibodies in serum.[6] Crystalline pellets from the bottom of the tubes after centrifuging were mounted directly in the holder of a gas-tight x-ray camera and attached to the usual diffraction outfit[7] installed in a cold room maintained at 36° C. Desiccation or deliquescence of the sample was prevented by filling the camera with helium containing an appropriate amount of water vapor. Measurements of the spacings and estimates of the relative intensities of the principal diffraction lines obtained from crystalline masses prepared (1) by chemical means, (2) by ultracentrifuging a solution of the chemically purified virus protein and (3) by ultracentrifuging the clear plant juice itself are listed in Table I. As the data suggest, the three patterns are indistinguishable one from another.

TABLE I

OBSERVED SPACINGS AND RELATIVE INTENSITIES OF X-RAY DIFFRACTIONS FROM CRYSTALLINE TOBACCO MOSAIC VIRUS PROTEINS

Intensities	Specimens of lines from samples crystallized by Ultra-centrifugation		
	Chemical means*	From solution of purified protein	From plant juice
Faint	37 A.	35 A.	36 A.
Very faint	28	....	....
Medium	20.8	20.7	20.6
Very faint	16.2	14.5	14.6
" "	14.2		
Strong	11.0	11.2	11.1
Faint	10.2	....	....
Medium	9.2	9.2	9.2
"	7.44	7.43	7.43
Faint	6.5	6.4	....
Very faint	5.7	5.7	....
Faint	5.44	5.45	5.44
Medium (probably not single)	4.95	5.02	4.94
"	4.71	4.72	4.71
"	4.44	4.46	4.46
Faint	4.08	4.10	4.10
Medium	3.88	3.88	3.88

* Data of reference 3. The camera used in photographing the ultracentrifuged samples did not have a sufficient radius and resolving power to record the spacings larger than 40 A.

CONCLUSION

From these observations it is apparent that a crystalline virus protein can be obtained directly by ultracentrifuging the juice of plants infected with the tobacco mosaic disease. The x-ray patterns of this crystalline material and of the protein prepared from the juice by chemical means are indistinguishable; the two substances, must, therefore, be substantially identical.

RALPH W. G. WYCKOFF
ROBERT B. COREY
ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, NEW YORK

[1] We are indebted to W. M. Stanley, of the Department of Animal and Plant Pathology of the Rockefeller Institute, for the plant materials used in this study.

[2] W. M. Stanley, SCIENCE, 81: 644, 1935; *Jour. Biol. Chem.*, 115: 673, 1936.

[3] R. W. G. Wyckoff and R. B. Corey, *J. Biol. Chem.*, 116: 51, 1936.

[4] J. Biscoe, E. G. Pickels and R. W. G. Wyckoff, *Jour. Exp. Med.*, 64: 39, 1936.

[5] J. H. Bauer and E. G. Pickels, *Jour. Exp. Med.*, 64: 503, 1936.

[6] R. W. G. Wyckoff, SCIENCE, 84: 291, 1936.

A RELATION BETWEEN SEED ATTACHMENT AND CARPEL SYMMETRY AND DEVELOPMENT IN PRUNUS[1]

IN connection with more detailed studies of developmental morphology of deciduous fruits[2,3] and of the effect of embryo development upon fruit development,[4] a relation has appeared between carpel development and the position of seed attachment which is of some interest both in relation to fruit development and to the general topic of symmetry.

The observations cover several hundred specimens from different varieties of peach (*Prunus Persica* Batech), plum (*P. domestica* L., *P. insititia* L., *P. salicina* Lindl., and *P. americana* Marsh.), the sweet cherry (*P. avium* L.), the sour cherry (*P. Cerasus* L.), the apricot (*P. Armeniaca* L.), and the nectarine (*P.*

[7] R. W. G. Wyckoff and J. B. Lagsdin, *Rev. Sci. Instr.*, 7: 35, 1936.

[1] New York State Agricultural Experiment Station Journal Series No. 165.

[2] H. B. Tukey, *Proc. Am. Soc. Hort. Sci.*, 30: 209–318, 1933.

[3] H. B. Tukey, *Proc. Am. Soc. Hort. Sci.*, 31: 125–144, 1934.

[4] H. B. Tukey, *Bot. Gaz.*, 98: 1–24, 1936.

Persica var. *nucipersica* Schneid). In all, 24 varieties have been examined.

The fruit of these species consists of a single carpel. On each carpel an anatropous ovule is borne, which is attached near the distal end of the ovarian cavity. Just before full bloom and prior to fertilization, one ovule aborts, although occasionally both may persist, more commonly in some varieties than in others. The remaining ovule develops into a seed.

It is common observation that many fruits of these species are asymmetric or unequally sided, the one side or "half" of the fruit being more fully developed than the other. Furthermore, the larger side may often be more highly colored, more highly flavored and may soften and ripen earlier. In some varieties this situation is pronounced, as in the Imperial Epineuse plum, where in some seasons the smaller side of the carpel remains hard and green and fails to develop to good edible and marketable condition, although the larger side matures and ripens properly. Likewise, the Crawford type peaches and fruits, with a pronounced bulge or "belly" along the ventral suture, show an uneven development of sides to a marked degree. In other varieties, with fruit smooth in contour, and more round or oval in shape, the unevenness of sides is less noticeable.

The pit is similar to the flesh in being more fully developed on the side which shows greater flesh development. This relation between pit and flesh is to be expected since the pit and the flesh together constitute the carpel, the inner portion of which becomes schlerenchymatous and hard and separates as the stony pericarp or pit, while the outer portion becomes soft and is the fleshy pericarp or edible portion of the fruit.

In cases of asymmetric fruits, examination of the stony pericarp and the point of attachment of the seed shows that the seed is attached to the larger and better developed side of the carpel (Fig. 1). In instances where both seeds develop, this difference between sides is not apparent and the fruits appear symmetric. It is possible to forecast the side to which the seed is attached by observing the larger and better developed side either of the fleshy pericarp or the stony pericarp. The fact that the symmetry of the stony pericarp is affected in the same manner as the fleshy pericarp indicates that the influence of seed attachment occurs early in the development of the peach, since the stony pericarp is fully outlined in the carpel at an early date and the stony pericarp has become hard by 49 days after fertilization[2] in a variety which requires 144 days to fruit ripening.

The arrangement of the vascular system of fruits of these species offers a ready explanation for this situation. Using the peach as an example, the dorsal side of the carpel (identified as a single line running from

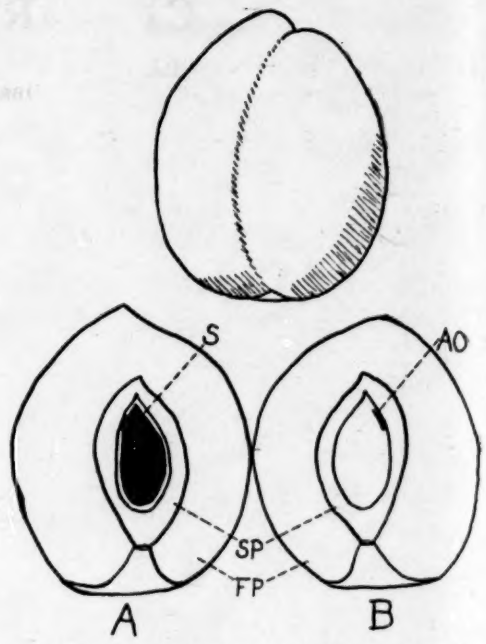

FIG. 1. Unequally sided peach fruit. The side of the carpel (A) to which the seed (S) is attached is more fully developed than the side (B) to which the abortive ovule (AO) is attached. SP = stony pericarp; FP = fleshy pericarp.

proximal to distal end) is homologous with the midrib portion of a folded leaf. The ventral suture (identified by its broadness and double fold appearance) is the region where the two edges of the carpel meet. It has been demonstrated[5] that although the edges of the carpel are adjacent, yet there is no actual union of edges along the ventral suture of the pit at the distal end. Accordingly, while the two ovules within the ovarian cavity are adjacent, they are separated morphologically from each other a distance equal to the transverse circumference of the fruit.

The two ventral bundles, which supply vascular connection to the ventral region of the fruit, are thus widely separated morphologically, although adjacent in their position in the fruit. Since a growing embryo establishes a deficiency gradient towards which food materials move and favors the development of the associated vascular system, it might be expected that the side of the carpel to which the embryo is attached would be the side more fully developed.

Finally, it is well known that the set of fruit is affected by fertilization and seed formation.[6] Moreover, seed development[7] affects the entire plant and may even result in the failure of female reproductive organs to develop in subsequently developing flowers, thus bringing about sterility of those flowers. More recently it has been shown that the development of an embryo within a developing fruit may have an even more local influence and may affect the development of that fruit as a whole.[3] Now it appears that

[5] C. H. Ragland, *Proc. Am. Soc. Hort. Sci.*, 31: 1-21, 1934.

[6] A. E. Murneek, *Proc. Am. Soc. Hort. Sci.*, 33: 4-6, 1936.

[7] A. E. Murneek, *Plant Phys.*, 7: 79–90, 1932.

in the case of a simple fruit the position of the embryo in relation to the carpel and its point of attachment to that carpel markedly affects the shape and development of a portion of the fruit. Thus, the dominating effect of the embryo upon fruit development is extended to even a portion of a carpel.

NEW YORK STATE AGRICULTURAL EXPERIMENT STATION,
GENEVA, NEW YORK
H. B. TUKEY

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A SIMPLIFIED AUTOMATIC RECORDER FOR IONOSPHERIC HEIGHT MEASUREMENT

THE purpose of this article is to describe a satisfactory method of photographically recording virtual heights of the various layers of the ionosphere without the use of complicated equipment. Errors of considerable magnitude which are likely to be overlooked by investigators, regardless of the nature of the recording equipment, are also discussed.

The general method of photographing radio pulse reflections from the ionosphere as seen on a cathode ray oscilloscope screen is not new, but usually the equipment is of special design and often quite complicated. The accuracy of the method described herein is practically as good as that of some of the intricate and expensive methods now in use.

A diagram of the oscilloscope screen (Fig. 1) shows from left to right the ground pulse, an E reflection and an F reflection, respectively. It will be observed that the entire screen is masked, with the exception of the base or zero-signal line. When a synchronous pulse is received, it causes the sweep line to be deflected upward behind the mask, leaving a blank space in the line.

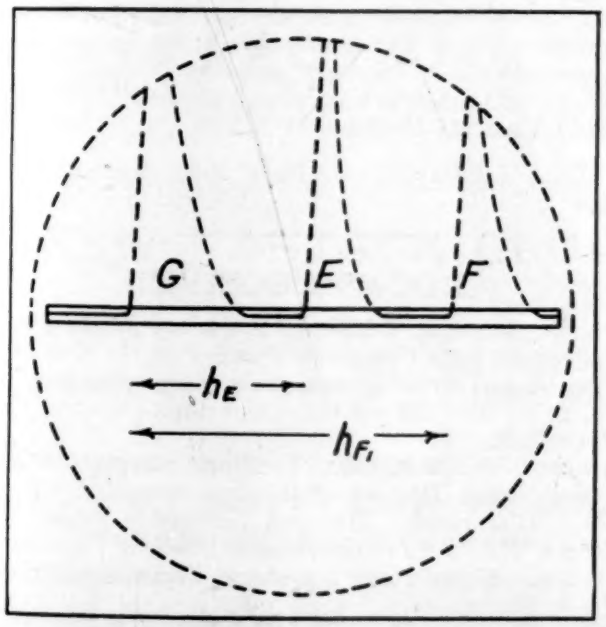

FIG. 1. Screen of oscilloscope showing ground pulse G with two reflected impulses E. and F.

The recording device consists of an ordinary camera focused on the oscilloscope screen and a hand-wound clockwork attached to the key for slowly winding up the film. It is obvious that if the clockwork runs at a constant rate, the time scale will not be linear, as the film will speed up with increasing roll diameter. After one film had been run through it was found that the speed at the end was practically double that at the beginning. In subsequent recordings, the governor on the clockwork was adjusted every half hour so that the film passed by the lens at nearly a constant rate. Also, a calibrating wave was introduced at half-hour intervals. Even this speed adjustment is an unnecessary refinement, since the time scale is marked off in desired intervals by the introduction of the calibrating wave or simply by closing the camera shutter for a few seconds.

The film from which the prints in Fig. 2 were made was driven at about six inches per hour, and each of the sections shown represents a fifteen minute observation. The distance between any two adjacent peaks on the 3,000 cycle calibrating wave shown at the end of the second recording represents a layer height of 50 km. The layer heights as measured at the beginning of the second recording are 115 km, 225 km and 355 km for the E, F-1 and F-2 layers, respectively. These particular runs were made soon after sunset on a frequency of 2,398 kc. Police stations operating on adjacent channels caused the five or six smears on the recordings. It is interesting to note that in the latter

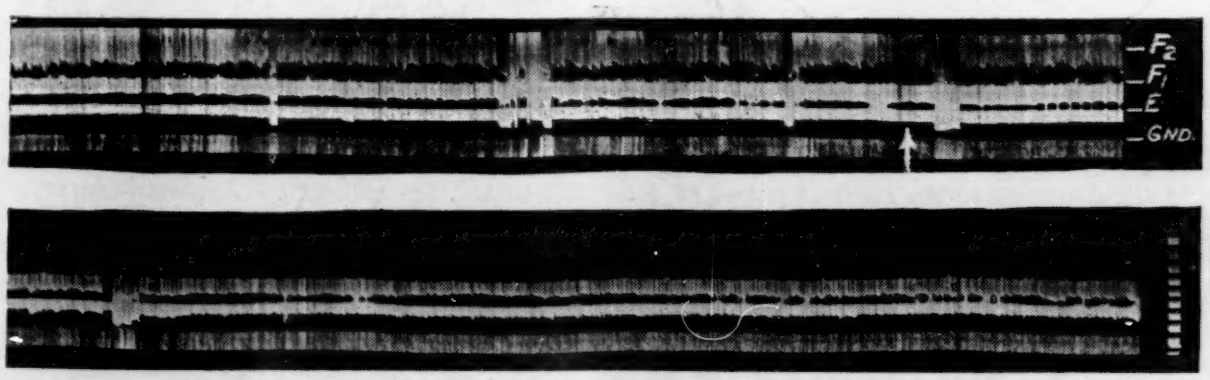

FIG. 2. Photographic records of ionospheric heights made shortly after sunset.

part of the second recording (Fig. 2) the F-1 layer is composed of a wide band of reflections extending nearly up to the F-2 region. The boundary line of the E layer is quite distinct at all times, but this is not true of the F layers on the second recording. Rapid changes in signal strength and fluctuations of layer height were the causes of this condition. In other words, there was no sharp boundary existing at the time mentioned.

The heights of the layers are obtained from the recordings by measuring the distance between the edges of the unexposed portions of the film with a traveling microscope. The edges from which measurements are made are indicated in Fig. 2 by the letters Gnd, E, F_1, F_2. It is preferable to use the negatives directly for this purpose, since they are somewhat sharper than the positives.

This recording system has one inherent error which is common to all others with which the writers are familiar, namely, that changes in the strength of a received reflection produce what appears to be a change in the virtual height of the layer. This error arises because the time taken for the signal to pass through the receiver changes with input signal strength. The time lag is measured as shown in Fig. 3 by impressing the radio frequency pulse directly upon the deflecting plates of the oscilloscope. The pulse, after passing through the receiver, appears slightly to the right of the r.f. pulse. The distance D-1 is a measure of the time lag of a strong pulse and the distances D-2, and D-3 those of weaker ones.

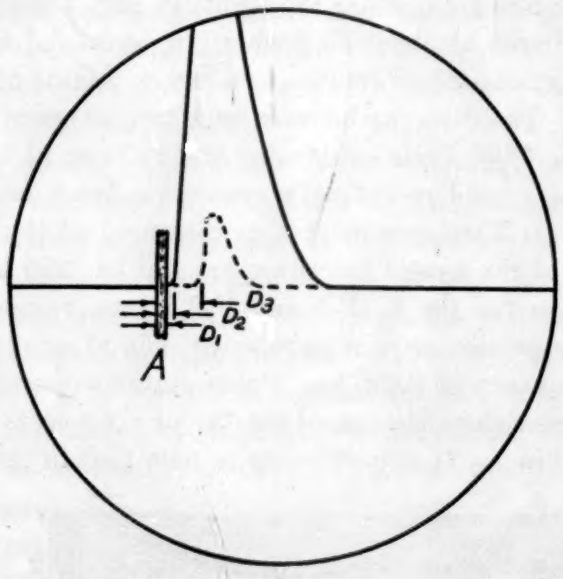

FIG. 3. *A* marks the position of a pulse which is impressed directly upon the oscilloscope itself. D-1, D-2, D-3 represent the distances to the right of pulses of different strengths which have passed through the receiver.

In the case of the National Fb-7 receiver, which is generally considered to be very satisfactory for ionospheric work, the lag is about 5 km for a strong pulse and about 20 km for a weak one. The effect of layer height apparently changing with variations in signal strength is clearly shown in Fig. 2 at the point indicated by the arrow. In this case the reflection became very weak and vanished for a short period of time. The height apparently changed from 127 km to 119 km in less than half a minute, but actually very little if any change took place.

This error may be largely eliminated by calibrating the receiver so that the lag for any value of signal strength is known. A correction can then be applied to the recorded data.

The error just discussed has seemingly been neglected by many investigators. A recent paper by E. C. Halliday[1] is of interest due to the high accuracy claimed (± 0.5 km). In the method described, the time scale was greatly expanded to permit ease of measurement and the front edges of the pulses were caused to intersect the sweep line at a definite angle. While these are decided improvements, they do not correct the error due to receiver lag. Statements have been made that the layer heights will change as much as ten kilometers in less than one minute. Such changes are probably caused by variations in the signal strength of the reflections and not by sudden fluctuations in the height of the layer.

R. C. COLWELL
N. I. HALL
L. R. HILL

WEST VIRGINIA UNIVERSITY

[1] E. C. Halliday, *Proc. Phys. Soc. London*, 48: 421, 1936.

BOOKS RECEIVED

BATESON, GREGORY. *Naven: A Survey of the Problem Suggested by a Composite Picture of the Culture of a New Guinea Tribe Drawn from Three Points of View.* Pp. xvii + 296. 28 plates. Cambridge University Press, Macmillan.

BREWSTER, WILLIAM. *October Farm; From the Concord Journals and Diaries of William Brewster.* Pp. xv + 285. Illustrated. Harvard University Press. $2.50.

FEATHER, N. *An Introduction to Nuclear Physics.* Pp. x + 213. 21 figures. 3 plates. Cambridge University Press, Macmillan.

GIBSON, CHARLES S. *Essential Principles of Organic Chemistry.* Pp. viii + 548. Cambridge University Press, Macmillan.

GRIFFITH, R. H. *The Mechanism of Contact Catalysis.* Pp. xi + 208. 90 figures. Oxford University Press. $5.00.

HUTCHINSON, G. E. *The Clear Mirror; A Pattern of Life in Goa and in Indian Tibet.* Pp. xi + 171. 13 plates. Cambridge University Press, Macmillan. $2.50.

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KARLSON, PAUL. *The World Around Us; A Modern Guide to Physics.* Pp. x + 293. 165 figures. 9 plates. Simon and Schuster. $3.00.

SWEETMAN, HARVEY L. *The Biological Control of Insects.* Pp. xii + 461. 142 figures. Comstock. $3.75.

WARDEN, CARL J. *The Emergence of Human Culture.* Pp. 189. Macmillan. $2.00.